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Removal of Organic Contaminants from Drinking Water Supply at Glen Cove New York, Phase II

Nebolsine Kohlmann Ruggiero Engineers, New York

Prepared for

Municipal Environmental Research Lab.
Cincinnati, OH

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EPA 600/2-82-027
March 1982

PB82-258963

REMOVAL OF ORGANIC CONTAMINANTS FROM DRINKING WATER SUPPLY AT GLEN COVE, N.Y.

Phase II

by

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New York, N.Y.

U.S. EPA Cooperative Agreement No. CR 806355-01

Project Officer

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MUNICIPAL ENVIRONMENTAL RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
CINCINNATI, OHIO 45268

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16. ABSTRACT

This research program was initiated with the overall objective of obtaining relevant design parameters and capital and operating costs of both adsorption and aeration techniques for the removal of specific organic contaminants from the City of Glen Cove's drinking water supply. Major contaminants present are: trichloroethylene, tetrachloroethylene, cis-1,2-dichloroethylene, and 1,1,1-trichloroethane.

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The results of Phase II supported the conclusions of Phase I, (EPA-600/2-80-198, November 1980) and further indicated the applicability of both adsorption on resin and aeration as treatment for groundwater containing the above listed organic compounds. The testing of resins indicated that the use of columns in a downflow mode of operation, with upflow steam regeneration, appears to be the best approach. With proper steam regeneration, the resin returns to better than 90% of the original adsorptive capacity of the virgin resin and its continued use results in lengths of runs similar in time to those of the virgin resins. The regeneration of activated carbon with steam was not successful under the test conditions and, therefore, this approach is not recommended. The aeration testing indicated a slight edge in removal efficiencies for the packed column over the diffused aeration column. However, its additional cost may outweigh its advantage. The results from the small cooling tower indicate that this type of cooling tower would not be acceptable for treatment of the contaminated water present at Glen Cove.

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FOREWORD

The U.S. Environmental Protection Agency was created because of increasing public and government concern about the dangers of pollution to the health and welfare of the American people. Noxious air, foul water and spoiled land are tragic testimonies to the deterioration of our natural environment. The complexity of that environment and the interplay of its components require a concentrated and integrated attack on the problem.

Research and development is that necessary first step in problem solution; it involves defining the problem, measuring its impact, and searching for solutions. The Municipal Environmental Research Laboratory develops new and improved technology and systems to prevent, treat, and manage wastewater and solid and hazardous waste pollutant discharges from municipal and community sources, to preserve and treat public drinking water supplies, and to minimize the adverse economic, social, health and aesthetic effects of pollution. This publication is one of the products of that research and provides a most vital communication link between the researcher and the user community.

The results of the second phase of a pilot plant study to remove organic contaminants from ground water are reported here. Further examination of synthetic resin adsorption with in-place steam regeneration and aeration techniques was made and cost analyses for each approach were computed.

Francis T. Mayo, Director
Municipal Environmental
Research Laboratory

ABSTRACT

This research program was continued with the overall objectives of obtaining relevant design parameters and capital and operating costs of both adsorption and aeration techniques for the removal of specific organic contaminants from the City of Glen Cove's drinking water supply. Major contaminants present are trichloroethylene, tetrachloroethylene, cis-1,2-dichloroethylene and 1,1,1-trichloroethane.

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This report was submitted in fulfillment of Cooperative Agreement No. 806355-01 by Nebolsine Kohlmann Ruggiero Engineers, P.C. for the City of Glen Cove, N.Y. under the partial sponsorship of the U.S. Environmental Protection Agency. This report covers the period May 27, 1980 to January 30, 1981 and covers phase II of the project. The third and final phase is scheduled for completion in calendar year 1982.

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Mr. Eric Isacoff of Rohm and Haas Company was always available for advice about the resin. He also helped in conducting the regeneration attempts, and facilitated the transfer of information necessary in such projects.

We would also like to thank the Mayor of the City of Glen Cove, Mr. Joseph Hurley, Director of Public Works for the City of Glen Cove and the Glen Cove Water Department, in particular, Anthony Caruso and Mrs. Margaret d'Esposito, as well as the men stationed at the test site.

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SECTION 1

INTRODUCTION

The City of Glen Cove, New York, located on the north shore of Long Island and receiving its drinking waters from wells, experienced a water shortage in 1977 due to the closing of wells because of organic contamination. Approximately 25% of the water supply was closed due to the presence of trichloroethylene, tetrachloroethylene and cis-1,2-dichloroethylene above the New York State's maximum allowable limits of 50 micrograms per liter (ug/l) for any one organic contaminant and a total allowable limit of 100 ug/l for all such compounds. Faced with this reduced water supply, the City of Glen Cove was forced to purchase water from neighboring communities and it began a crash program to install new wells. Realizing that the contamination could migrate throughout the aquifer, the City initiated a search to find methods of treating the contaminated water.

Since the contamination present at Glen Cove is also a nationwide problem, the U.S. EPA was interested in the Glen Cove problem and, consequently, funded a research project under a Cooperative Agreement (CR806353-01) in 1978 to study methods for reducing the contaminants to acceptable levels.

The City of Glen Cove, with U.S. EPA concurrence, retained the consulting engineering firm of Nebolsine Kohlmann Ruggiero Engineers, P.C. (NKRE) to build, operate, monitor and maintain a pilot plant at Glen Cove's Carney Street well field, and to evaluate the results. This pilot plant, which received water from Carney Street Well No. 22, was constructed during the early part of 1979 and began operation at the end of March. The pilot plant was operated for approximately nine months ending in early January 1980 during which time two methods of treating the contaminated water were tested: diffused aeration to strip the contamination from the water using the counterflow approach, and adsorption of the contaminants by synthetic resin. The results of this testing, which are presented in report number EPA-600/2-80-198 titled "Removal of Organic Contaminants from Drinking Water Supply at Glen Cove, N.Y. - Phase I", indicated that the aeration system, with the proper air to water ratios, could reduce the contaminants below current New York State maximum allowable

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levels and that the resin was capable of lowering the contaminants to below 1 microgram per liter (ug/l), producing an acceptable quality water for several months.

Results from Phase I warranted extending the test program to continue development of the technologies, with the following major objectives:

ADSORPTION STUDIES

1. Evaluate the resin system in both upflow and downflow modes of operation.

2. Improve the steam regeneration system to eliminate steam condensation and losses by applying steam concurrently and countercurrently to flow. Investigate higher steam loadings.

3. Determine the feasibility of regenerating granular activated carbon with steam.

4. Evaluate the resin system for its corrosive properties and the correct materials for construction.

AERATION STUDIES

Continue the diffused aeration testing and install and evaluate, for comparative purposes, a packed column aeration system and a small cooling tower.

Discussions with the U.S EPA's Drinking Water Research Division in Cincinnati, Ohio and with the City of Glen Cove resulted in the approval of Phase II of the study in March 1980. NKRE was again hired as the subcontractor and Phase II was conducted from May 27, 1980 to January 30, 1981. Results of the study are presented in this report.

SECTION 2

CONCLUSIONS

RESIN ADSORPTION STUDIES

1. As in Phase I, the test results using Rohm and Haas' Ambersorb XE-340 indicated that this resin was capable of reducing the levels of contaminants to very low concentrations and, in most cases, virgin or freshly regenerated resins achieved reductions of each contaminant to less than 1 ug/l. These results were achieved for the following influent ranges: cis-1,2-dichloroethylene, 28-79 ug/l; 1,1,1-trichloroethane, 3-7 ug/l; trichloroethylene, 117-277 ug/l, and tetrachloroethylene, 33-207 ug/l.

2. Again, the general order of breakthrough was cis-1,2-dichloroethylene, trichloroethylene, then tetrachloroethylene at an application rate of 4 gpm/ft^3 (0.42 lpm/m^3) of adsorbent corresponding to an empty bed contact time of 1.9 minutes.

3. The best mode of operation proved to be countercurrent with downward flow application and upward steam regeneration.

4. The ability of the resin to be regenerated with steam, achieving better than 90 percent of virgin adsorbent capacity, was conclusively demonstrated during this phase.

5. Steam regeneration techniques were further defined in Phase II; however, they require further development. Approximately 20 bed volumes of steam at an application rate of one bed volume per hour were required to regenerate the resin. The collection of the condensate, separation of the organic phase for disposal and recycling of the aqueous phase to the next-to-be-regenerated resin column was determined feasible as a condensate treatment approach during this phase.

6. As indicated in the Phase I report, the water quality target level is an important factor in interpretation

of the data, sizing and estimating the cost of a full-scale system and determining the operation of a system. Using the application rate of 4 gpm/ft^3 (0.42 lpm/m^3) of adsorbent, (1.9 minute empty bed contact time) and the downward flow application mode, the service time to achieve an effluent level of 20 ug/l of trichloroethylene was approximately 160 days; however, if maintaining an effluent level of 5 ug/l for trichloroethylene is desired, the service time would be reduced to 110 days.

7. Corrosion studies performed with carbon steel coupons indicated that the resin does not increase corrosivity over that caused by the water itself.

8. The estimated capital and annual operating cost for a full-scale resin installation was determined for the same plant capacities used in the Phase I report from 1-5 mgd (3,785-18,925 m^3/day). These costs were computed using three columns in series operating in the downward flow mode at 4 gpm/ft^3 (0.42 lpm/m^3) and considering steam regeneration of each column three times per year. The estimated capital costs range from \$308,250 to \$953,400 and the annual operating costs, including amortization, are from \$0.12 to \$0.22 per 1000 gallons (3.79 m^3) of treated water. This cost includes an estimated cost of handling and disposal of the contaminated steam condensate and concentrated organics.

GRANULAR ACTIVATED CARBON STUDIES

The purpose of these studies was not to evaluate the adsorptive abilities of the ICI and Calgon activated carbons tested but rather to evaluate the feasibility of regenerating activated carbon with steam. The results of the three 24-hour regeneration attempts (two on the ICI carbon and one on the Calgon carbon) showed that the regeneration of activated carbon with steam, utilizing the steam equipment and conditions designed to regenerate resin, was not successful under the conditions tested.

DIFFUSED AERATION STUDIES

1. Diffused aeration appears to be a viable treatment option for the removal of volatile organic contaminants from groundwater and this approach could be used as a pre-treatment to additional treatment if more stringent water quality is required than that achievable by diffused aeration.

2. As concluded in the Phase I report, aeration can reduce the contaminants present in the well water at Glen Cove to levels below present New York State guidelines, and to levels which might be acceptable throughout the nation. This was true greater than 98% of the time for all air to water ratios tested (5:1, 10:1 and 15:1) during Phase II and for all contaminants involved.

3. The estimated capital costs of a full-scale diffused aeration system for plant capacities from 1-5 mgd (3,785-18,925 m^3/day) range from $228,200 to $470,700. This cost includes the replacement of existing high pressure well pumps after treatment. The estimated total annual operating costs, including amortization, are about $0.19-$0.33 per 1000 gallons (3.79 m^3) of treated water. This cost is based on Glen Cove's comparatively high electrical cost of $0.09 per kWh and may be lower in other areas.

4. A minimum amount of testing at the end of the program, to determine a mass transfer coefficient, indicates that additional reduction of contaminant levels may be possible using two-stage diffused aeration.

PACKED COLUMN AERATION STUDIES

1. All statements and conclusions discussed under diffused aeration studies also apply to the packed column aeration studies.

2. The use of the packing material, purchased from Munters Corporation, in the unflooded mode produced the best results with a slight improvement over that of diffused aeration at the air to water ratios of 5 to 1 and 10 to 1; however, at an increased estimated capital and operating cost.

3. The estimated capital costs for the full-scale operation system using the same capacities as those utilized in the cost estimates for diffused aeration (1-5 mgd), and including the same items, range from $275,000 to $650,500

which is 20 to 45 percent higher than that for diffused aeration. This increased cost is due to the required packing and storage below the unflooded aeration units, which would be a requirement at most utilities using well water as a source for its supply. The estimated total annual operating cost, including amortization, is about \$0.17 to \$0.32 per 1000 gallons (3.79 m^3) of treated water. These costs could be reduced if environmentally acceptable alternate methods of air introduction can be demonstrated and utilized. These estimated costs are based on the \$0.09/kWh electrical cost in the Glen Cove area.

INDUCED DRAFT COOLING TOWER STUDIES

A small demonstration model of an induced draft cooling tower supplied by Baltimore Air Coil was utilized in this testing. Utilizing an air flow meter it was determined that this unit was capable of producing air to water ratios ranging from 200:1 to 700:1 at flow application rates of 2 gpm to 4 gpm respectively. Based on testing in this range, the removal efficiency was rather low, being between 48 to 61 percent average removal for the contaminants present. The unit did not achieve present New York State guidelines for trichloroethylene and seldom met the present New York State guidelines of 100 ug/l for total organic levels. Therefore, this type of unit, by itself, is not considered feasible for treating contaminated groundwater, but may possibly serve as a pretreatment method to final treatment. However, it should be emphasized that the unit used was a demonstration unit for sales purposes and a unit designed for this specific application, or other type of cooling tower units, could possibly be suitable for the treatment of contaminated groundwater.

ADDITIONAL OBSERVATIONS

1. While performing analytical determinations on the Glen Cove water supply at the U.S. EPA's laboratories in Cincinnati, three additional contaminants were identified in the well water: 1,1-dichloroethylene, 1,1-dichloroethane and 1,2-dichloroethane. Concentrations present were 0.3 ug/l, 4.6 ug/l and 10.8 ug/l, respectively.

2. During this phase of testing there was a definite shift in the contamination levels of trichloroethylene and tetrachloroethylene. During Phase I testing, trichloroethylene was the major contaminant, averaging 205 ug/l, followed by tetrachloroethylene averaging 75 ug/l.

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During the second half of Phase II a shift in contamination level took place and near the end of this phase trichloroethylene concentrations decreased to an average of 130 ug/l while tetrachloroethylene concentrations increased to an average of 200 ug/l. The reason for this water quality change is unknown. Two possible explanations for causing this change could be 1) a shift in wave front or 2) a recent dumping of contaminant may have occurred.

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SECTION 3

RECOMMENDATIONS

Reviewing the data developed during Phase I and this phase of testing, it becomes apparent that an efficient system for removing organic contamination would be one using aeration followed by adsorption. This approach would allow treatment by aeration to economically reduce all contamination levels and then polish the water by adsorption, thereby further reducing effluent levels to those required by guideline/standards, reducing regeneration frequencies and extending the length of service time for the adsorption system. Because this has not been previously tested on a pilot plant scale, the pilot plant operation should be continued to evaluate this approach. During this third phase of the pilot plant other gaps in the data base should also be evaluated. Major research areas for this third phase should be as follows:

COMBINED AERATION-ADSORPTION STUDIES

1. Determination of the best and most economical mix of aeration and resin to achieve the required water quality. Testing will include various air to water ratios and hydraulic loadings on the resin systems.

ADSORPTION STUDIES-RESIN

2. Testing to determine the maximum hydraulic loading for the resin system. All testing to date has utilized 4 gpm/ft^3 (0.42 lpm/m^3) which appears conservative. Only by determining the maximum hydraulic loading can the proper economics be determined. This hydraulic loading should be evaluated on a series resin system using both raw well water and aeration treated well water as influents.

3. Continuation of developing steam regeneration technique. In particular, to optimize the amount of steam required and to develop the proper handling and disposal of the steam condensate.

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DIFFUSED AERATION STUDIES

4. Evaluation of the effect of two-stage aeration to determine the level of contaminant removal achievable by aeration alone and the economic impact of this system.

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SECTION 4

PILOT PLANT FACILITIES

Based on the recommendations that appear in the Phase I report, various changes and modifications to the pilot plant equipment were made before Phase II began. These modifications and additions included a change in the size of columns used for the resin testing, the installation of activated carbon columns, a large steam supply, insulation and electric heating of steam piping and columns, and the installation of a packed aeration column and a small cooling tower for air stripping. It was also recommended that the smaller well in the area, Well No. 20, be connected to the system in an attempt to reduce the project electrical cost. Following the approval of the Phase II extension, the pilot plant was designed by NKRE and the plans were reviewed with U.S. EPA (MERL-DWRD).

The basic layout of the pilot plant facilities remained the same as in Phase I and the additions or modifications were made in the areas related to the particular testing. A schematic flow diagram of the Phase II pilot plant facilities is presented on Figure 1.

The same Well No. 22, having a capacity of 2 mgd (7570 m^3/day) used in Phase I testing remained connected to the system. In addition, a new pipe was installed connecting Well No. 20, having a capacity of 0.5 mgd (1900 m^3/day), in an attempt to reduce the electrical costs of the project.

The major additions and modifications to the resin testing system were made to facilitate the testing of upflow and downflow applications, countercurrent steam regeneration and to insure that pure steam was present for the regeneration of the resin.

To accomplish the desired testing on the resin system, three new columns, Nos. III, IV and V, shown on Figure I, were installed, each 4 inches (0.10 m) in diameter and 2.2 feet (0.67 m) high. This height allowed for 2 feet (0.61 m) of resin depth and ten percent freeboard. Water flow through the resin was in a downward mode for Column III and upward mode for Columns IV and V.

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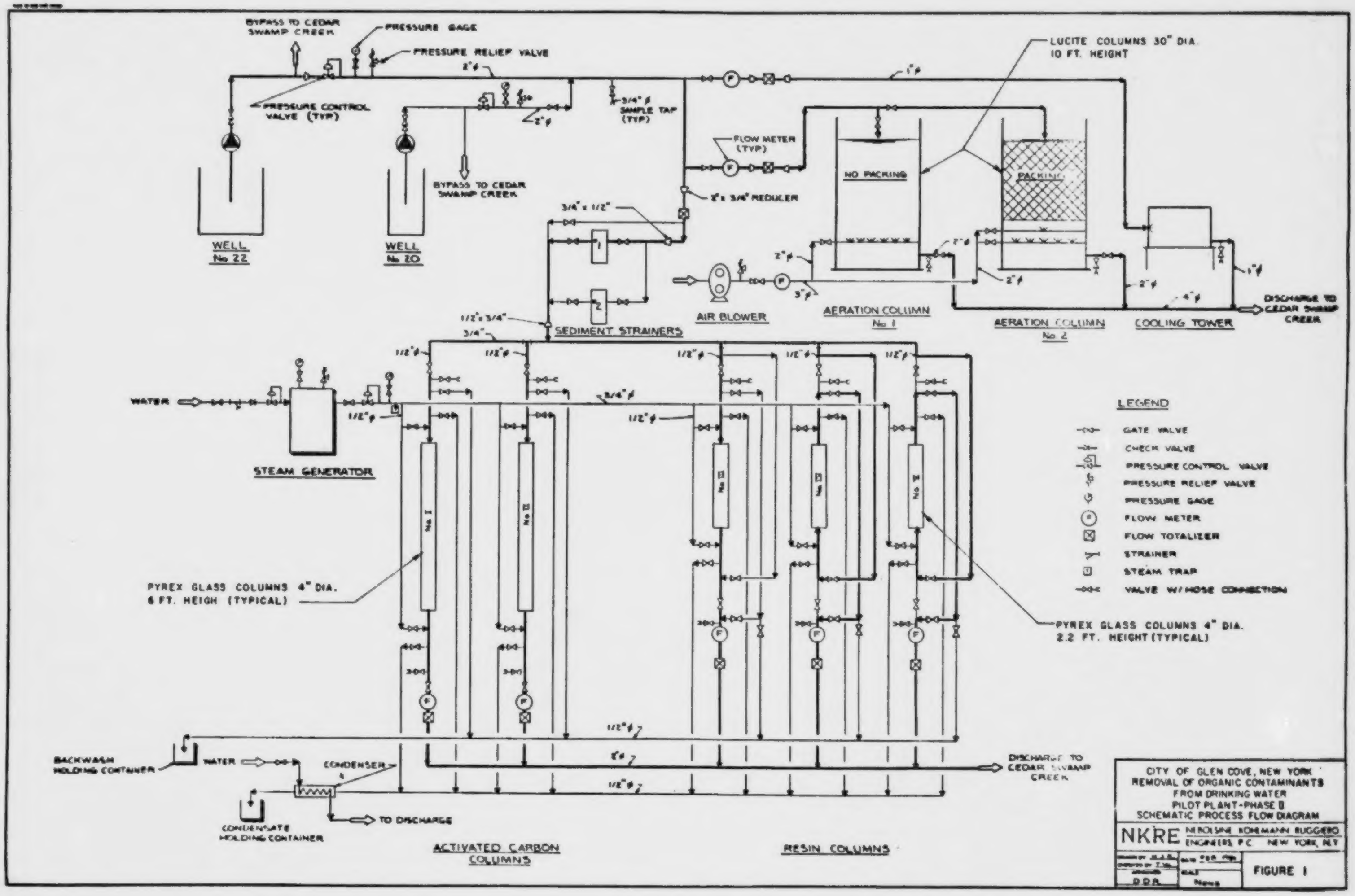
BYPASS TO CEDAR SWAMP CREEK
PRESSURE GAGE
PRESSURE RELIEF VALVE
PRESSURE CONTROL VALVE (TYP)
2" ϕ
3/4" ϕ SAMPLE TAP (TYP)
BYPASS TO CEDAR SWAMP CREEK
WELL No 22
WELL No 20
FLOW METER (TYP)
2" x 3/4" REDUCER
3/4" x 1/2"
1" ϕ
LUCITE COLUMNS 30" DIA. 10 FT. HEIGHT
NO PACKING
PACKING
2" ϕ
3" ϕ
4" ϕ
AIR BLOWER
AERATION COLUMN No 1
AERATION COLUMN No 2
COOLING TOWER
DISCHARGE TO CEDAR SWAMP CREEK
1 1/2" x 3/4"
3/4"
SEDIMENT STRAINERS
1/2" ϕ
3/4" ϕ
WATER
STEAM GENERATOR
No I
No II
No III
No IV
No V
PYREX GLASS COLUMNS 4" DIA. 6 FT. HEIGH (TYPICAL)
PYREX GLASS COLUMNS 4" DIA. 2.2 FT. HEIGHT (TYPICAL)
LEGEND
GATE VALVE
CHECK VALVE
PRESSURE CONTROL VALVE
PRESSURE RELIEF VALVE
PRESSURE GAGE
FLOW METER
FLOW TOTALIZER
STRAINER
STEAM TRAP
VALVE W/ HOSE CONNECTION
BACKWASH HOLDING CONTAINER
WATER
CONDENSER
CONDENSATE HOLDING CONTAINER
TO DISCHARGE
DISCHARGE TO CEDAR SWAMP CREEK
ACTIVATED CARBON COLUMNS
RESIN COLUMNS
CITY OF GLEN COVE, NEW YORK
REMOVAL OF ORGANIC CONTAMINANTS
FROM DRINKING WATER
PILOT PLANT-PHASE II
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FIGURE 1

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In order to insure that sufficient steam was available for regeneration, which was performed in a countercurrent direction to flow application, a higher capacity Chromalox electric steam generator was provided, capable of producing 100 lbs/hr of steam. To insure that true steam was used during regeneration, external heating devices were attached to the columns and on all piping of the steam system. The columns were heated during regeneration using removable two-feet long electrical heating mantles attached to the necessary temperature control devices. Electrical heat tracing tapes, including required temperature control devices and insulation was provided for all steam piping which included the piping from the steam generator to the column and the piping from the column to the steam condenser. Since concern was expressed that the fabricated condenser used in Phase I did not drain properly and possibly affected the amount of steam required for regeneration, a new commercial type steam condenser was purchased from American Standard Company and installed.

Phase II testing included the evaluation of the feasibility of regenerating granular activated carbon (GAC) with steam. To facilitate this evaluation, two six-feet high (1.83 m) columns, which were used in Phase I resin testing, were left in place and connected to the new steam system. These columns, designated No. I and II on Figure 1, were each loaded with a four foot depth of activated carbon and operated in a downward mode. Regeneration of these columns was attempted in an upward mode using electrical heating mantles to prevent the condensing of steam.

To continue the evaluation of aeration designs, a second column, identical to that used in Phase I aeration testing, was installed. Six feet of packing material purchased from Munters Corporation was placed in the column. This packing rested on a ledge two feet above the bottom of the column and air was applied below the packing either through stone diffusers or a hole in a pipe at the center of the packing. The packing was supplied in one-foot sections and was installed so that the orientation of the channels in the packing was altered from layer to layer. The space between the packing and the inside of the column was sealed at each one-foot interval to prevent air from circumventing the packing. Air to both the column used in Phase I and the new column was supplied from the same blower utilized during Phase I.

In order to evaluate the stripping efficiency of the cooling tower, a small demonstration model of an induced draft cooling tower, provided by Baltimore Air Coil, was installed. This model is based on a self-sustaining aerating system requiring no outside source of energy other than the water pressure itself.

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Required analyses were performed on the gas chromatograph system purchased for Phase I with the addition of a new recorder purchased from Varian Corporation.

These modifications and additions to the equipment from Phase I testing are shown in the photographs presented in Figures 2 and 3.

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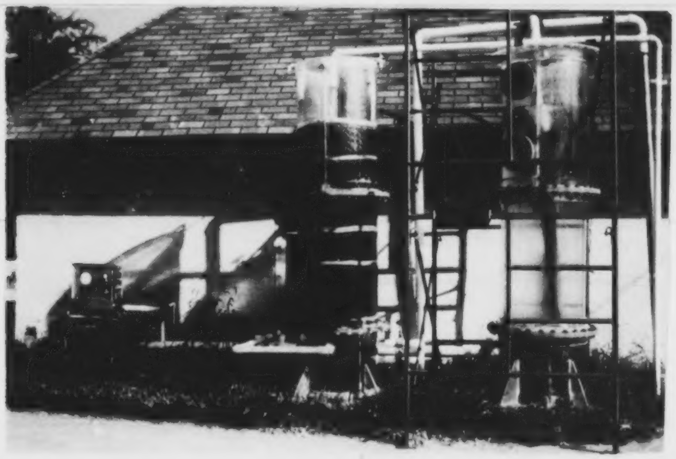
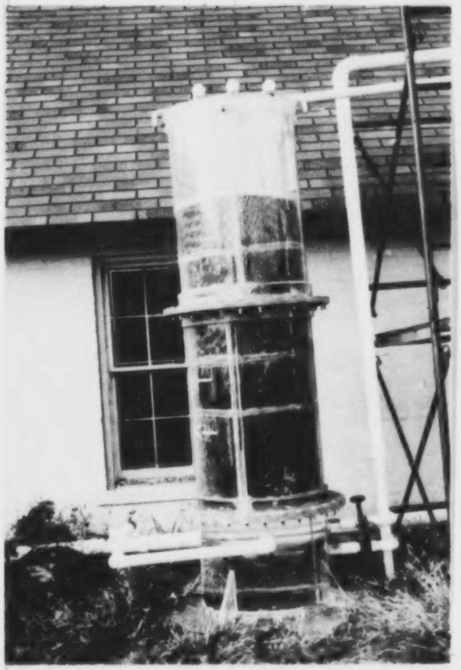
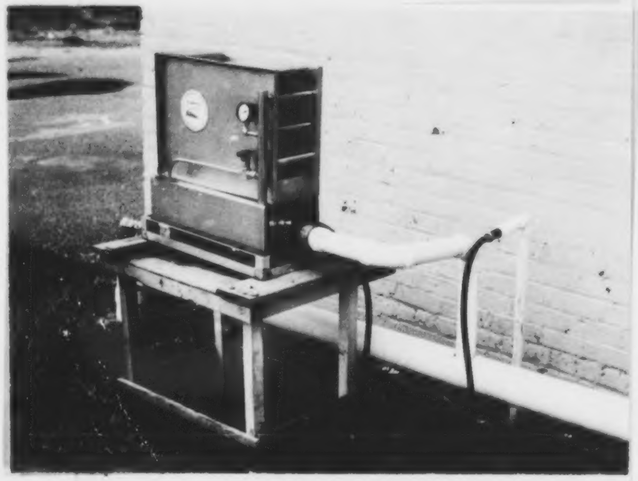


Phase II - Aeration Testing
(Induced Draft Cooling Tower, Packed
Aeration Column and Diffused Aeration
Column from Phase I)



Phase II - Packed
Aeration Column.



Phase II - Induced Draft
Cooling Tower

Figure 2

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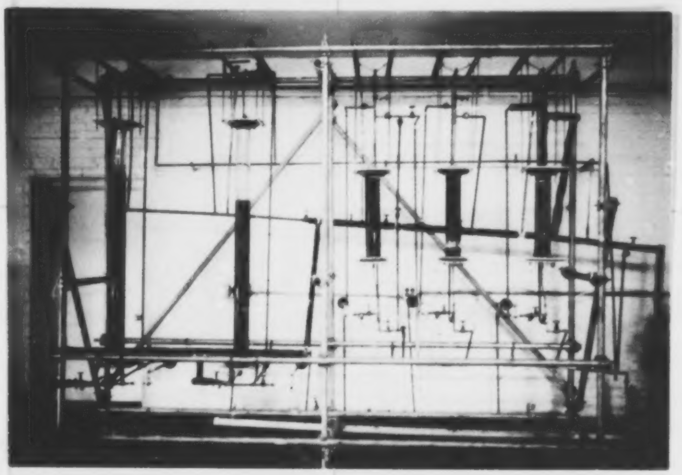
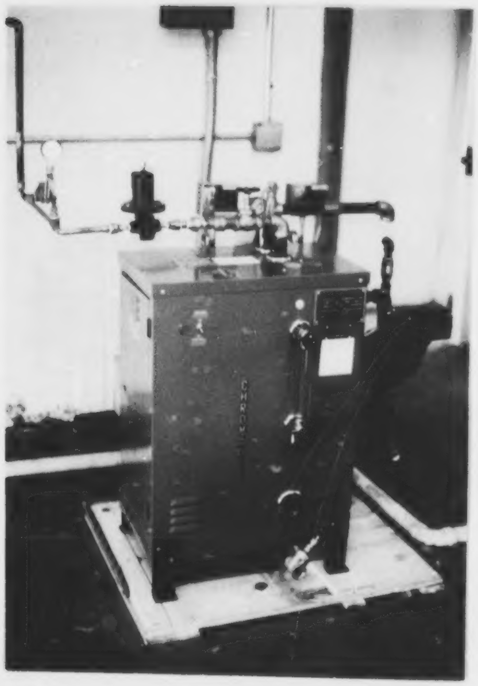
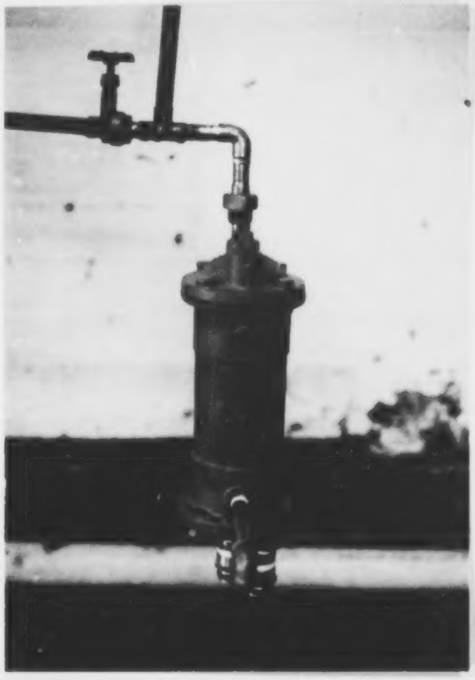


Phase II - Activated Carbon Columns (larger) and Resin Columns (shorter)



Phase II - Steam Generator



Phase II - Steam Condenser

Figure 3

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SECTION 5

TESTING PROGRAM AND OPERATION

The objective of the testing program for Phase II was the continuation and expansion of the Phase I program which is presented in the report EPA-600/2-80-198 "Removal of Organic Contaminants from Drinking Water Supply at Glen Cove, N.Y. - Phase I." The Phase II pilot plant program continued the evaluation of air stripping and resin adsorption as methods for the removal of trichloroethylene, tetrachloroethylene, cis 1,2-dichloroethylene and 1,1,1-trichloroethane from well water utilized as a drinking water supply. In addition, the regeneration of activated carbon by steam and alternate methods of aeration were also evaluated during this second phase.

The resin utilized in the Phase II testing was the same as that used for Phase I, Rohm and Haas' Ambersorb XE-340 ^{R}, which is designed for the removal of relatively non-polar organic molecules and halogenated aliphatics from water. Following the procedure described in the Phase I report the resin utilized in testing was first hydrated using methanol. Three test columns (Nos. II, IV and V on Figure 1, each with two feet (0.61 m) of resin) were utilized for the testing. The flow through each column was set at 42 gallons/hr (0.16 m^3/hr) which is twice the flow utilized in Phase I testing. The application rate, however, was maintained at 4 gpm/ft^3 of adsorbent (0.42 lpm/m^3) as utilized in Phase I, corresponding to a 1.9 minute empty bed contact time. Columns III and IV contained two feet (0.61 m) of virgin resin which had been used in Phase I and regenerated at the beginning of Phase II. The flow application for Columns IV and V was in the upflow mode while Column III operated in a downflow mode as indicated on Figure 4.

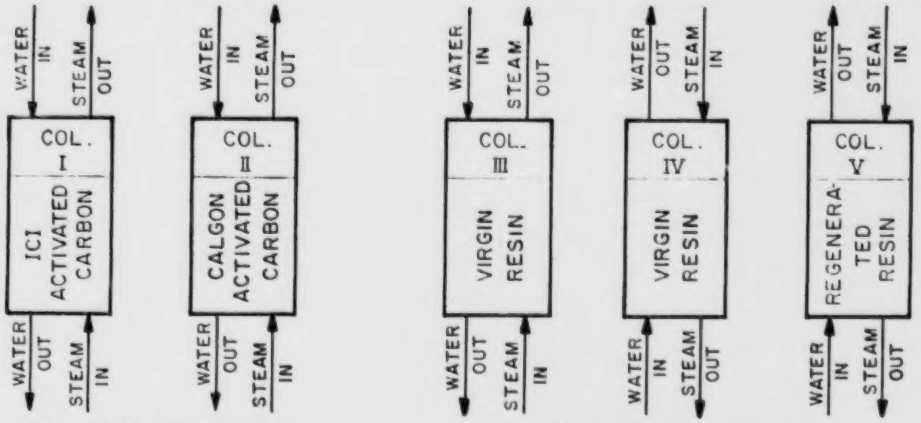
So that regeneration of granular activated carbon with steam could be evaluated, two of the six-foot (1.83 m) columns, Nos. I and II, utilized in Phase I, remained connected to the system and four feet (1.22 m) of activated carbon from ICI (H.D. 4000) and Calgon (Filtersorb 400), respectively, was placed in each. The flow was operated at 42 gal/hr (0.16 m^3/hr) in a downward direction for each column as shown on Figure 4, resulting in an empty bed contact time of about 3.7 minutes which is actually less than half of the minimum empty bed contact time recommended by the activated carbon suppliers.

This condition was utilized for the major portion of the testing because the major objective of the activated carbon testing was the evaluation of regeneration by steam and not contaminant removal efficiency by activated carbon. Based on this objective, it was decided to use this abnormally low empty bed contact time so that the activated carbon could load with organics faster requiring regeneration more frequently.

On May 16, 1980, the pump in Well 22 was turned on and was run for five days prior to feeding the test units to achieve peak contaminant levels. During this period, the resin in column V, which previously had been used in the 2 foot (0.61 m) depth resin column of Phase I, was regenerated. This was the first use of the new steam generating system.

The Phase I problem of reduced flow due to blockage caused by the formation of sedimentation on the top of the resin did not occur during Phase II. The use of teflon plates at both ends of the columns, and the spiral wound nylon cartridge filter installed prior to the columns, prevented solids formation. However, the accumulation of rust at the elbows near the flow meters did reduce flow through the columns. For this reason, and to have an accurate measurement of water processed, on July 3rd flow totalizers were added to each line after the flow meter. In addition, in order to determine the corrosivity of the water, and water with resin, steel coupons were set up on July 1st, one suspended in water and the other in the resin through which the water was flowing. On September 9th, two additional pairs of coupons were set up. All the coupons were run until December 22nd. This testing was performed in a small column other than those used for the actual adsorption testing.

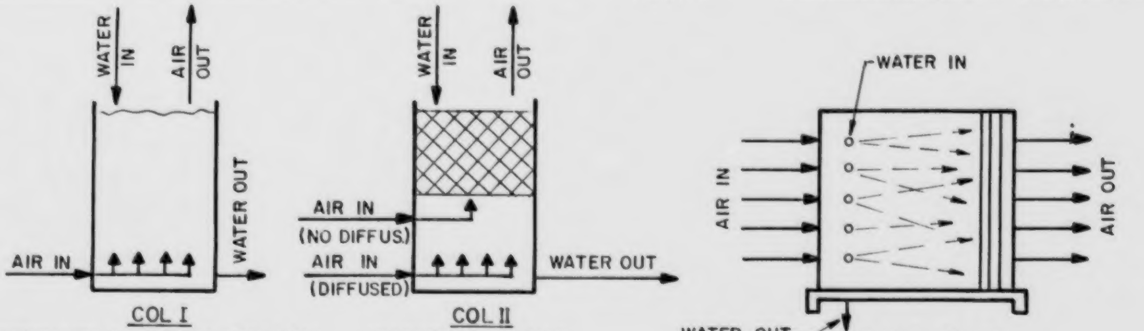
As in Phase I, the water flow through the aeration columns was 28 gal/min. (6.4 m^3/hr), corresponding to 10 min. residence time. The air to water ratio was varied by changing the air flow to the columns. Since the system was not designed to accurately control the air and water to the column simultaneously, first one column and then the other was tested. The water was aerated for at least one hour before sampling. The packed column had two modes of aeration: either through six diffuser stones or through a three-inch diameter hole. Both methods were tested separately. Sampling took place after at least one hour of aeration. Both aeration columns were operated using a counter current air to water flow mode as shown on Figure 4.


WATER IN
STEAM OUT
COL. I
ICI ACTIVATED CARBON
WATER OUT
STEAM IN
WATER IN
STEAM OUT
COL. II
CALGON ACTIVATED CARBON
WATER OUT
STEAM IN
WATER IN
STEAM OUT
COL. III
VIRGIN RESIN
WATER OUT
STEAM IN
WATER OUT
STEAM IN
COL. IV
VIRGIN RESIN
WATER IN
STEAM OUT
WATER OUT
STEAM IN
COL. V
REGENERA-TED RESIN
WATER IN
STEAM OUT

GRANULAR ACTIVATED CARBON COLUMNS

ROHM & HAAS XE-340 RESIN COLUMNS

ADSORPTION TESTING – FLOW AND STEAM APPLICATION MODES


WATER IN
AIR OUT
AIR IN
WATER OUT
WATER IN
AIR OUT
AIR IN (NO DIFFUS.)
AIR IN (DIFFUSED)
WATER OUT
WATER IN
AIR IN
AIR OUT
WATER OUT

COL I (DIFFUSED AERATION COLUMN)

COL II (PACKED COLUMN)

COOLING TOWER

AIR STRIPPING TESTS – FLOW APPLICATION MODES

PHASE II – PILOT PLANT TESTING MODES OF OPERATION

FIGURE 4

The cooling tower operated independently. As it generated its own air draft, the air-to-water ratio, which was determined by field measurements, was dependent on the water pressure. The tower's pressure gauge readings were correlated with the air to water ratios determined.

A normal sampling sequence consisted of collecting samples of the influent, which was common to all methods of treatment, and the effluents from the two carbon and three resin columns as well as from the cooling tower and the three modes from the two aeration columns. In addition, the temperature of the influent and aeration effluents were measured. The air temperature and humidity were determined. All flows and totalizer readings were recorded.

The samples and related data were taken, analyzed and recorded three times each week for the first month of operation, twice a week for the next month and thereafter weekly until November when bi-weekly sampling began. This sampling schedule was altered after regeneration when samples of the regenerated column's influent and effluent were collected more frequently.

The major purpose of testing steam regeneration was to determine the amount of steam required and the actual method of operating to successfully regenerate the resin. Based on a report which indicated the possibility of regenerating GAC with steam ("Controlling Trihalomethane Concentration in Ingradient Water" by David Palses, PhD), it was decided to evaluate the feasibility of regenerating GAC with steam using the equipment sized for the regeneration of the resin. All columns were regenerated by applying steam in a countercurrent direction to the water application as shown on Figure 4.

Column I, containing ICI granular activated carbon, was the first to be regenerated from August 25-27. This was followed by the regeneration of Column V from September 2-3. The steam condensate from the Column V regeneration, with its high concentrations of contaminants, was then introduced into Column IV before that column was regenerated on September 4-5, thereby "superloading" this column. Column II, containing Calgon carbon, was regenerated from October 1-3. Finally, Column III was regenerated during the period from November 12 to November 14.

All of the regenerations during Phase I, and the initial regeneration of each column during Phase II, were performed during normal working hours. The operation was shut down each night and was re-started each morning during the regeneration period until the predetermined time (24 hours for granular activated carbon) or contaminant condensate concentration (less than 100 mg/l for resin) was achieved. When the second round of regenerations during Phase II was begun, continuous regeneration was initiated to compare performance with intermittent operation. Again, Column I containing ICI activated carbon, was the first to require regeneration and this second regeneration of Column I was performed on November 18 and 19, 1980. Column IV was regenerated for a second time on January 13 and 14, 1981, and its condensate was used to "superload" Column V prior to its second regeneration on January 14 and 15, 1981. By this time, both carbon containing columns could have been regenerated again, but because it was felt that nothing new would be learned from any additional regeneration of the activated carbon columns, regeneration was not performed and the columns were allowed to operate until the end of the field program to gather data for more complete breakthrough curves.

Initially, the water level in both aeration columns was maintained at eight feet. This was just sufficient to cover the packing in the new column. An air-to-water ratio of 15:1 was used until July 21st, at which time it was changed to 10:1.

On September 18th, a spray head was added to the packed aeration column to facilitate the distribution of water over the flooded packing. The new head distributed the influent water over the entire top surface of the packing. On September 23rd, after normal sampling, the water level in the packed aeration column was lowered so that 1.5 ft. of the packing remained under water, while 4.5 ft. was exposed to air. On October 24th, the water level was dropped further so that the packing was unflooded and testing continued using this mode for the remainder of the Phase II testing period. Throughout these changes, the air-to-water ratio of 10:1 was maintained. On November 18th, the ratio was changed to 5:1 and was used for the remainder of the program.

At the end of the program, the packing was removed from the second column. The two columns were connected in series, with a pump to transfer the effluent from the first to the second column. On January 28th and 29th, a series of tests was run, in an effort to determine the mass transfer coefficient, using this system. Various air-to-water ratios were used. Influents and effluents from both columns were analyzed for the commonly present contaminants and for dissolved oxygen.

On January 30th, after more than eight months of operation, the pilot plant was shut down.

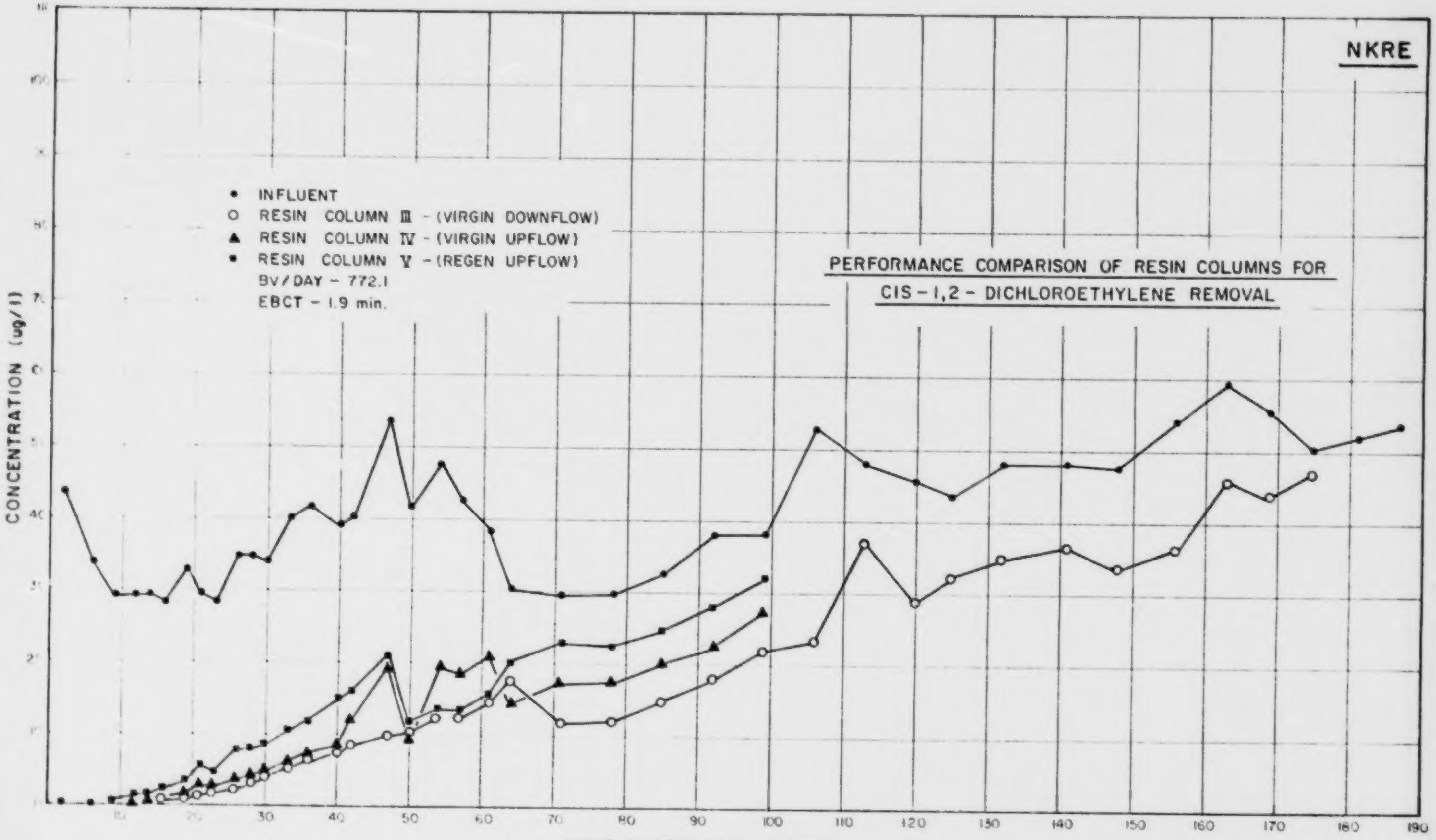
SECTION 6

RESULTS

ADSORPTION STUDIES - RESIN COLUMNS

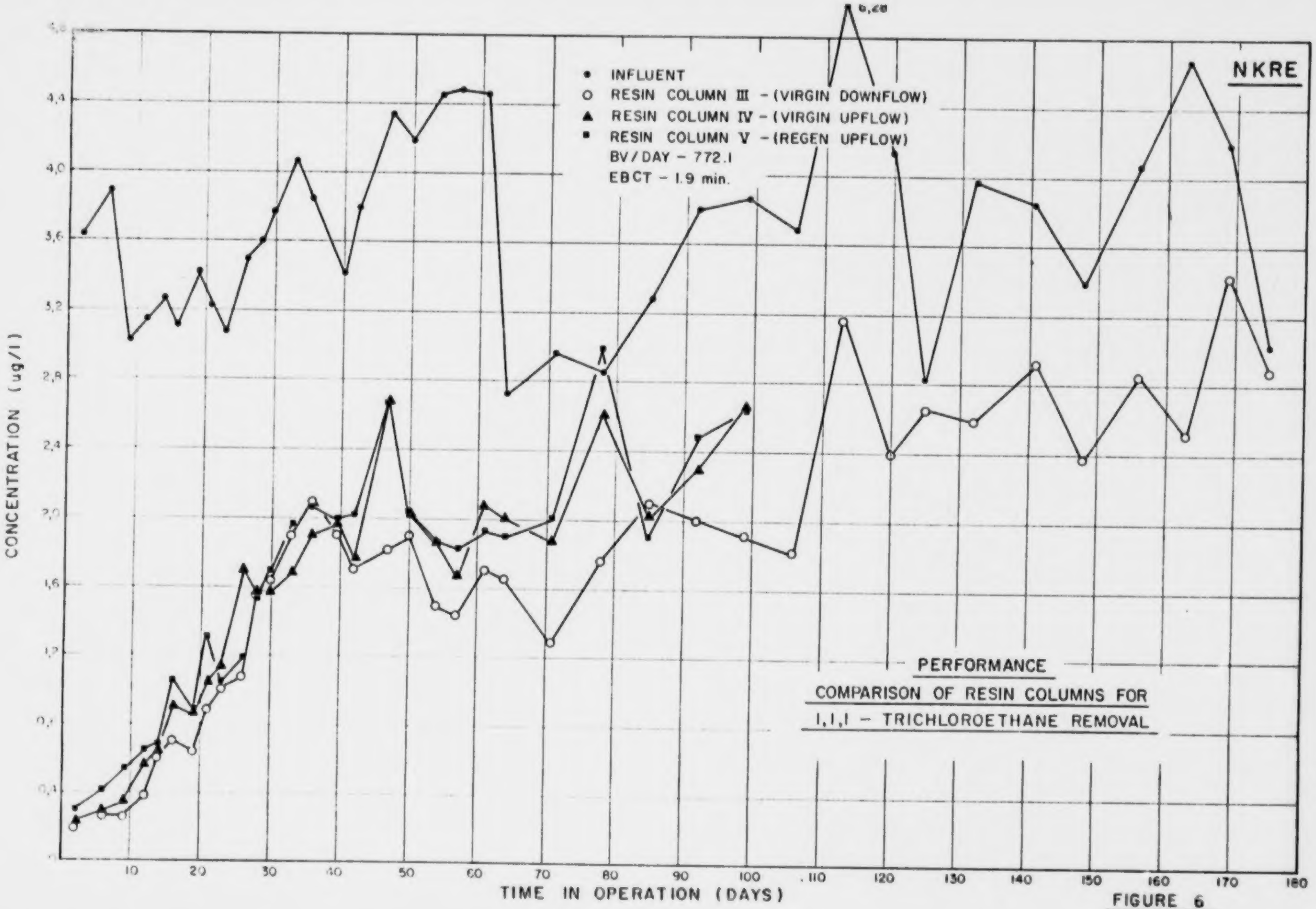
The adsorption studies, utilizing Rohm and Haas' Ambersorb XE-340 resin in Phase I, resulted in the conclusions that the contamination levels of cis-1,2-dichloroethylene, 1,1,1-trichloroethane, trichloroethylene and tetrachloroethylene could be reduced to less than 1 ug/l (ppb) for virgin and properly regenerated resins, that the only effect of resin depth was the increase in operating time before breakthrough which was in direct relationship to depth, and that steam regeneration of this resin appeared feasible but required further development. Based on these results the Phase II adsorption studies were performed with a constant amount and depth of resin of 2 feet (0.61 m) in each of the three columns tested and an application rate of 4 gpm/ft^3 of adsorbent (0.42 lpm/m^3) which resulted in an empty bed contact (EBCT) of approximately 1.9 minutes corresponding to approximately 772.1 bed volumes per day (BV/day). This testing phase also compared the upward and downward flow application modes and compared the use of virgin and regenerated resins. To facilitate testing, Columns III and IV were loaded with virgin resin and Column V was loaded with resin previously used and regenerated in Phase I. Columns IV and V were operated in the upward flow mode while Column III operated in the downward mode.

The performance of the three resin columns is compared on Figures 5 through 8. It appears that resin Column III was the most effective, followed by Columns IV and V, for which there was little observable difference in performance. Differences in column performance may be more readily observed in Figure 9, which represents the number of days for each contaminant to reach specified (5, 10, 20 and 40 ug/l) effluent concentrations. Since the influent of 1,1,1-trichloroethane did not exceed 5 ug/l, it was not plotted in this manner. Similarly, tetrachloroethylene never exceeded 5 ug/l in the effluent of Column IV, indicated by a single point on the graph. Again, the superiority of Column III was observed and Column IV's performance slightly exceeded that of Column V except for trichloroethylene. It is, therefore, evident that the downflow mode of operation resulted in lower contaminant levels, and



PERFORMANCE COMPARISON OF RESIN COLUMNS FOR CIS-1,2-DICHLOROETHYLENE REMOVAL

FIGURE 5

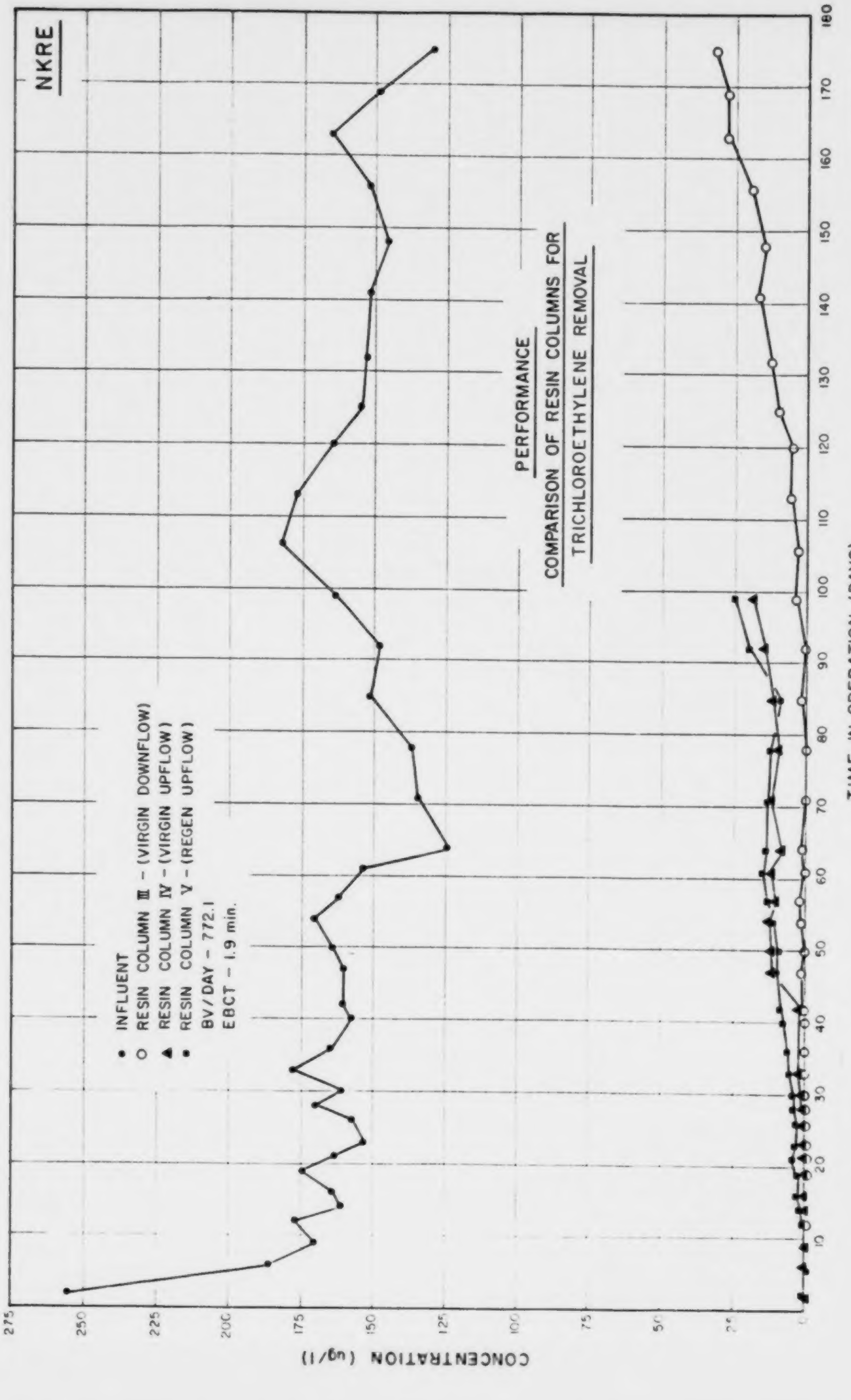


PERFORMANCE

COMPARISON OF RESIN COLUMNS FOR

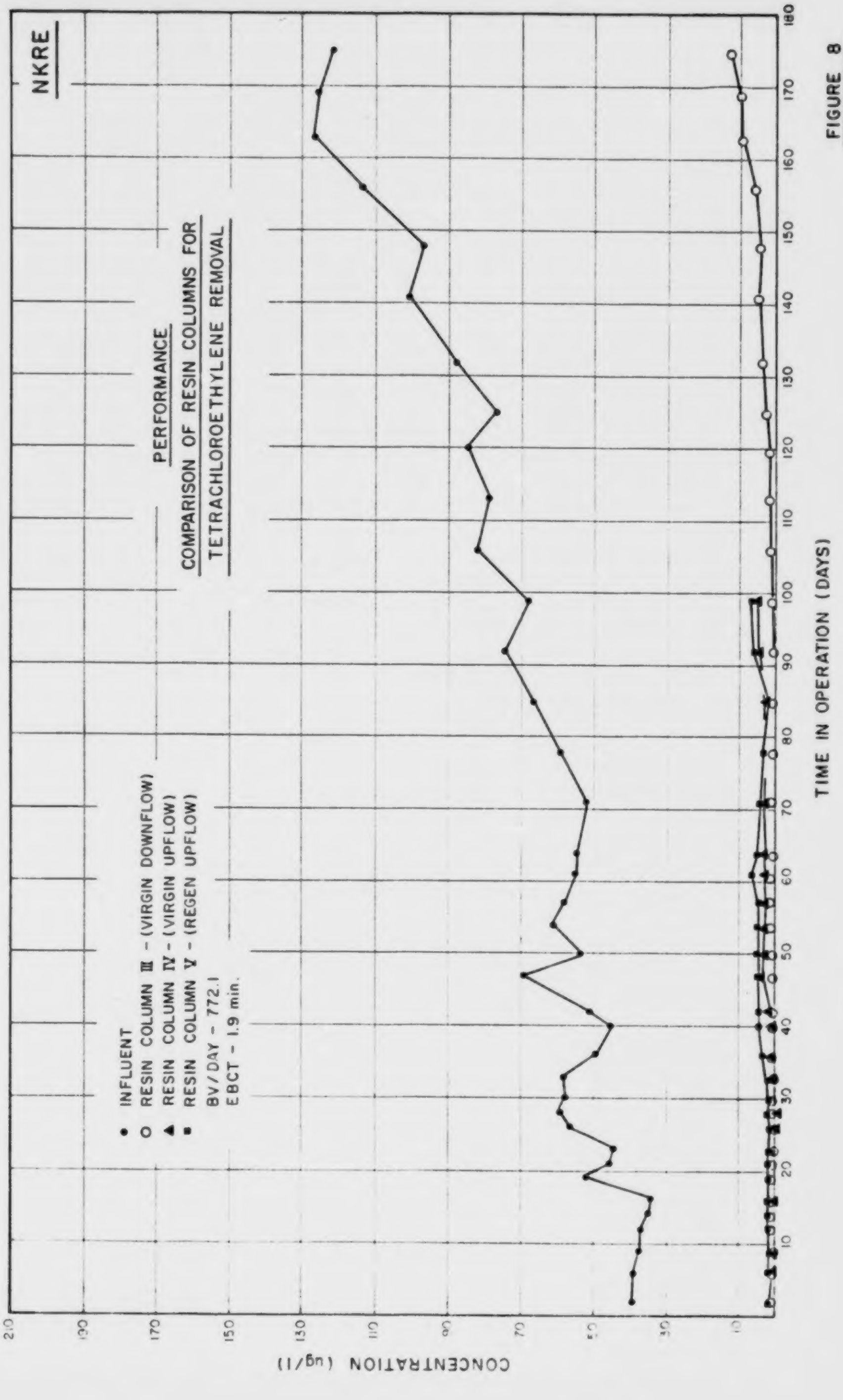
1,1,1 - TRICHLOROETHANE REMOVAL

FIGURE 6



PERFORMANCE
COMPARISON OF RESIN COLUMNS FOR
TRICHLOROETHYLENE REMOVAL

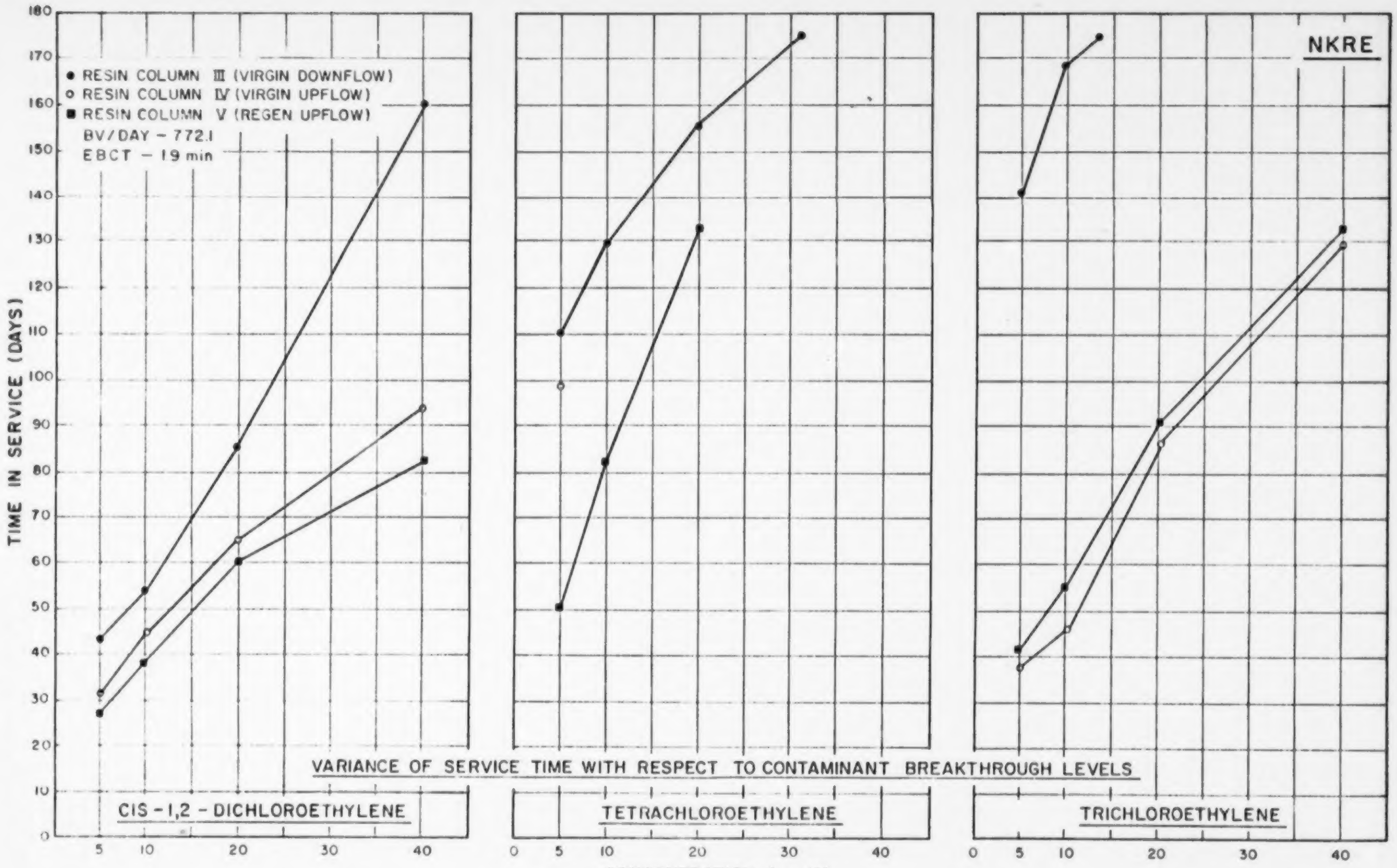
FIGURE 7



PERFORMANCE

COMPARISON OF RESIN COLUMNS FOR TETRACHLOROETHYLENE REMOVAL

FIGURE 8



VARIANCE OF SERVICE TIME WITH RESPECT TO CONTAMINANT BREAKTHROUGH LEVELS

FIGURE 9

virgin resins in the same mode of operation performed slightly better than the regenerated resin. The data presented on Figure 9 indicate the importance of desired target level so that proper design, operating procedures and cost can be determined.

As noted in Phase I of this study, cis-1,2-dichloroethylene was the first compound to saturate the resin. The performance of Column III observed from Figure 9, shows the following service times to reach an effluent level of 5 ug/l: 43 days for cis-1,2-dichloroethylene, 110 days for trichloroethylene, and 142 days for tetrachloroethylene. Therefore, it is evident that the resin columns were most effective in removing tetrachloroethylene, and least effective in removing cis-1,2-dichloroethylene. Another important observation is that, prior to regeneration, the effluent level for each contaminant was maintained below 50 ug/l, the current N.Y. State guideline level. This was true for Resin Column III, which operated for 175 days prior to regeneration, and for Columns IV and V, which operated for about 98 days before regeneration.

The results from the regenerations of all resin columns, which are fully discussed in Section 7, show that the effluent concentrations, even after regeneration, produce an acceptable effluent quality and the regenerated resin produces a breakthrough curve relatively close to virgin resin.

As a part of the resin testing, the corrosivity of the resin was evaluated. This was accomplished by placing steel coupons in the resin with water and the water above the resin. The results of this study, which are presented in Appendix C, indicate that the resin does not increase the normal corrosivity of the water.

ADSORPTION STUDIES - GRANULAR ACTIVATED CARBON (GAC)

As previously indicated, the purpose of adsorption testing of activated carbon was to assess the feasibility of regenerating spent activated carbon with steam, rather than to determine the adsorptive ability of the carbon. Because the hydraulic loading is more than twice the manufacturer's recommendation, thereby resulting in an empty bed contact time of half the minimum required, no attempt was made to evaluate the adsorption results of the activated carbon or compare them to each other or to the resin. Therefore, the discussion pertaining to activated carbon is covered under Section 5, Regeneration.

AERATION AND AIR STRIPPING STUDIES

The aeration studies utilizing diffused aeration in Phase I resulted in the conclusions that diffused aeration is definitely a feasible method of treating groundwater containing cis-1,2-dichloroethylene, 1,1,1-trichloroethane, trichloroethylene and tetrachloroethylene, that aeration at various air to water ratios can reduce contamination well below current New York State guidelines, and that diffused aeration has no appreciable impact on contamination of the ambient air or creating a waste disposal problem. Based on these results, it was decided to continue the aeration testing in Phase II to further develop design parameters for diffused aeration to compare diffused aeration to packed column aeration and to evaluate a cooling tower as a method of air stripping contamination from groundwater.

As indicated in the Phase I report, aeration is not affected by the build-up of contaminants as are adsorption systems and, therefore, it is independent of time. Considering this, the evaluation of aeration is based on the removal of contaminants for several air to water ratios (volume to volume).

During the Phase II test period relative efficiencies of three methods of aeration; diffused aeration column, packed aeration column and induced draft cooling tower, were determined. In addition, the packed aeration column evaluation consisted of determining the effect of introducing air into the column below the packing media by two methods, stone diffusers and a hole in the air pipe at the center of the media. The packed column was operated with the media flooded, partially flooded and above water surface, or unflooded. Variables in the testing program were the air to water ratios (15:1, 10:1 and 5:1), the water depth in the packed aeration columns, and the water flow to the induced draft cooling tower.

Aeration testing for both the unpacked and packed columns, at an air to water ratio of 15:1, continued for 20 individual sampling dates. The same air to water ratio was utilized for both air introduction systems, diffuser stones and hole, in the packed column. On the 21st sampling date a ratio of 10:1 was initiated for all aeration column systems and continued at this ratio until the 43rd sampling day. During this period, on the 35th day of sampling, the water level in the packed column was lowered so that only 25 percent (1.5 feet (0.46 m)) remained flooded or under water. On the 38th day of testing the water surface was lowered to the bottom of the media so the packing was completely above water, or unflooded, and testing continued in this mode until the completion of Phase II. The final air to water ratio of 5:1 for this phase was introduced on the 43rd sampling day and was utilized until the end of Phase II testing.

Because the induced draft cooling tower was a small demonstration unit, no air to water ratio data were available. The air to water ratios therefore had to be determined in the field by measuring the air flow utilizing a hand-held flow meter at three different water application rates; 2.5 gpm (9.5 lpm), 3.0 gpm (11.4 lpm) and 3.5 gpm (13.2 lpm), and the resulting linear calibration curve is shown on Figure 10. Air to water ratios ranged from 350:1 to 600:1.

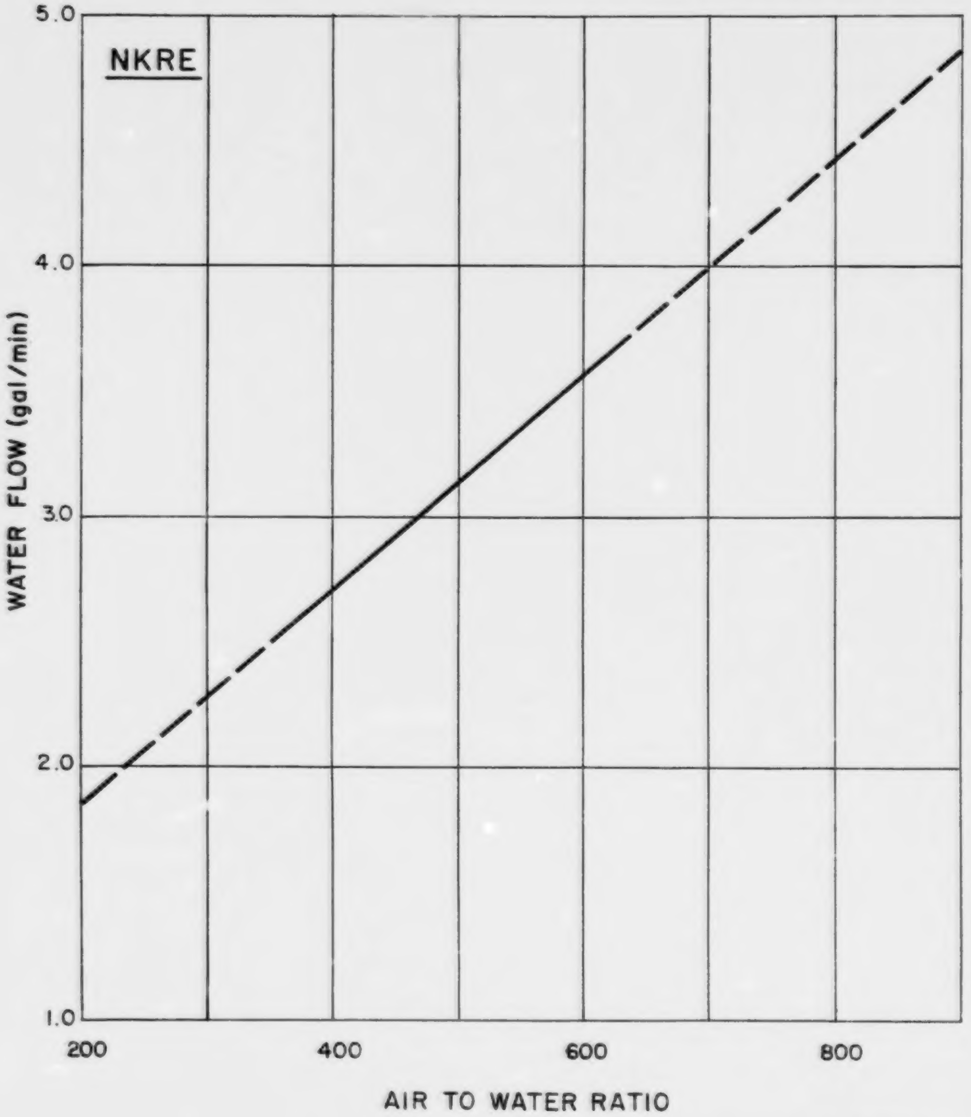
Tables 1 and 2 present the average contaminant influent and effluent levels, and the percent removal efficiency for each of the aeration systems at the tested air to water ratios and Table 3 summarizes the aeration column's removal efficiency.

It can be seen from these tables that the cooling tower was the least effective method of contaminant removal. Its highest average removal, 62%, corresponded to the lowest average removal efficiency achieved by the three remaining aeration methods.

Overall efficiency of the other aeration methods must be viewed in context with the air to water ratio being used. The aeration column alone achieved the greatest overall contaminant removal (84%) at an air to water ratio of 15:1. The next highest removal efficiencies (83%) were achieved by the unflooded packed column with air introduced by stone diffusers at an air to water ratio of 10:1.

Table 3 also shows that the packed column with stones using unflooded conditions was the most efficient aeration method at air to water ratios of 5:1 and 10:1, and that the aeration column alone was the most effective method at a ratio of 15:1.

The important effect of the various air to water ratios is further illustrated in Figures 11 and 12. It is clear from these graphs that increased contaminant removals correspond to increased air to water ratios for the aeration column and for the packed column with a hole. For these two systems, the lowest average contaminant removal occurred at an air to water ratio of 5:1, and the highest average contaminant removal occurred at a ratio of 15:1. It appears that the performance of the packed column with stones was the least affected by different air to water ratios, but was affected by the depth of water in the packing area producing the best results at the air to water ratio of 5:1 with the media above water level. The graphical presentation of data for the packed columns is intended to show the effect of the different water levels in



INDUCED DRAFT
COOLING TOWER
AIR TO WATER RATIO
VERSUS FLOWS

FIGURE 10

TABLE 1

AERATION COLUMNS PERFORMANCE
(Average values in ug/1)

Air: Water Ratio	Contaminant	Diffused Aeration Column			Packed Column-S* (Flooded)			Packed Column-S* (Unflooded)			Packed Column-H* (Flooded)			Packed Column-H* (Unflooded)		
		Ave. Infl.	Ave. Effl.	Ave.% Remov.	Ave. Infl.	Ave. Effl.	Ave.% Remov.	Ave. Infl.	Ave. Effl.	Ave.% Remov.	Ave. Infl.	Ave. Effl.	Ave.% Remov.	Ave. Infl.	Ave. Effl.	Ave.% Remov.
5:1	cis-1,2-dichloroethylene	62.3	27.8	55				62.3	17.8	71				62.3	20.8	67
	Trichloroethylene	131.1	47.4	64				131.1	23.0	82				131.1	35.3	73
	Tetrachloroethylene	155.7	41.7	73				155.7	18.8	88				155.7	29.8	81
	1,1,1-trichloroethane	4.0	1.73	57				4.0	1.0	75				4.0	1.5	63
10:1	cis-1,2-dichloroethylene	43.2	13.8	68	41.1	14.6	64	54.7	13.0	76	40.7	16.0	61	54.7	15.1	72
	Trichloroethylene	150.2	38.8	74	152.9	35.6	77	149.0	23.4	84	152.9	41.6	73	149.0	28.6	81
	Tetrachloroethylene	85.0	17.8	79	75.0	10.9	85	122.0	12.8	88	74.4	13.6	82	122.0	16.7	86
	1,1,1-trichloroethane	3.8	1.2	68	3.8	1.1	71	4.0	0.7	82	3.7	1.3	65	4.0	0.9	77
15:1	cis-1,2-dichloroethylene	36.5	8.6	76	36.5	11.6	68				36.5	11.2	69			
	Trichloroethylene	170.8	23.3	86	170.8	31.0	82				170.8	28.9	83			
	Tetrachloroethylene	49.0	4.4	91	49.0	5.9	88				49.0	5.5	89			
	1,1,1-trichloroethane	3.7	0.7	81	3.7	1.0	73				3.7	1.0	73			

* Packed Column-S = Column packed using diffuser stones.

Packed Column-H = Column packed with air passing through a hole.

TABLE 2

COOLING TOWER PERFORMANCE
(Average Values - ug/l)

Air Water Ratio	Cis			1,1,1			Tri			Tetra			Average % Removal
	Inf.	Eff.	% Removal	Inf.	Eff.	% Removal	Inf.	Eff.	% Removal	Inf.	Eff.	% Removal	
200:1	29.6	15.3	48	3.15	1.44	54	149	68.5	54	42.6	18.7	56	53
300:1	43.1	18.0	58	3.76	1.80	52	157	67.6	57	85.9	39.0	55	56
400:1	45.7	17.1	63	4.47	1.57	65	187	75.0	60	78.0	31.4	60	62
500:1	48.9	17.8	64	3.86	1.63	58	154	62.0	60	98.4	40.5	59	60
550:1	38.3	13.8	64	3.65	1.83	50	161	58.8	63	57.9	22.0	62	60
600:1	43.5	15.6	64	3.85	1.73	55	155	61.2	61	65.9	24.9	62	61

TABLE 3

AERATION COLUMNS REMOVAL EFFICIENCY
(Average Overall Percentage)

Column Type	5:1	10:1	15:1
Diffused Aeration	62	72	84
Packed-S-Flooded	-	74	78
Packed-S-Unflooded	79	83	-
Packed-H-Flooded	-	70	80
Packed-H-Unflooded	71	79	-

Packed Column-S = Column packed using diffuser stones.

Packed Column-H = Column packed with air passing through a hole.

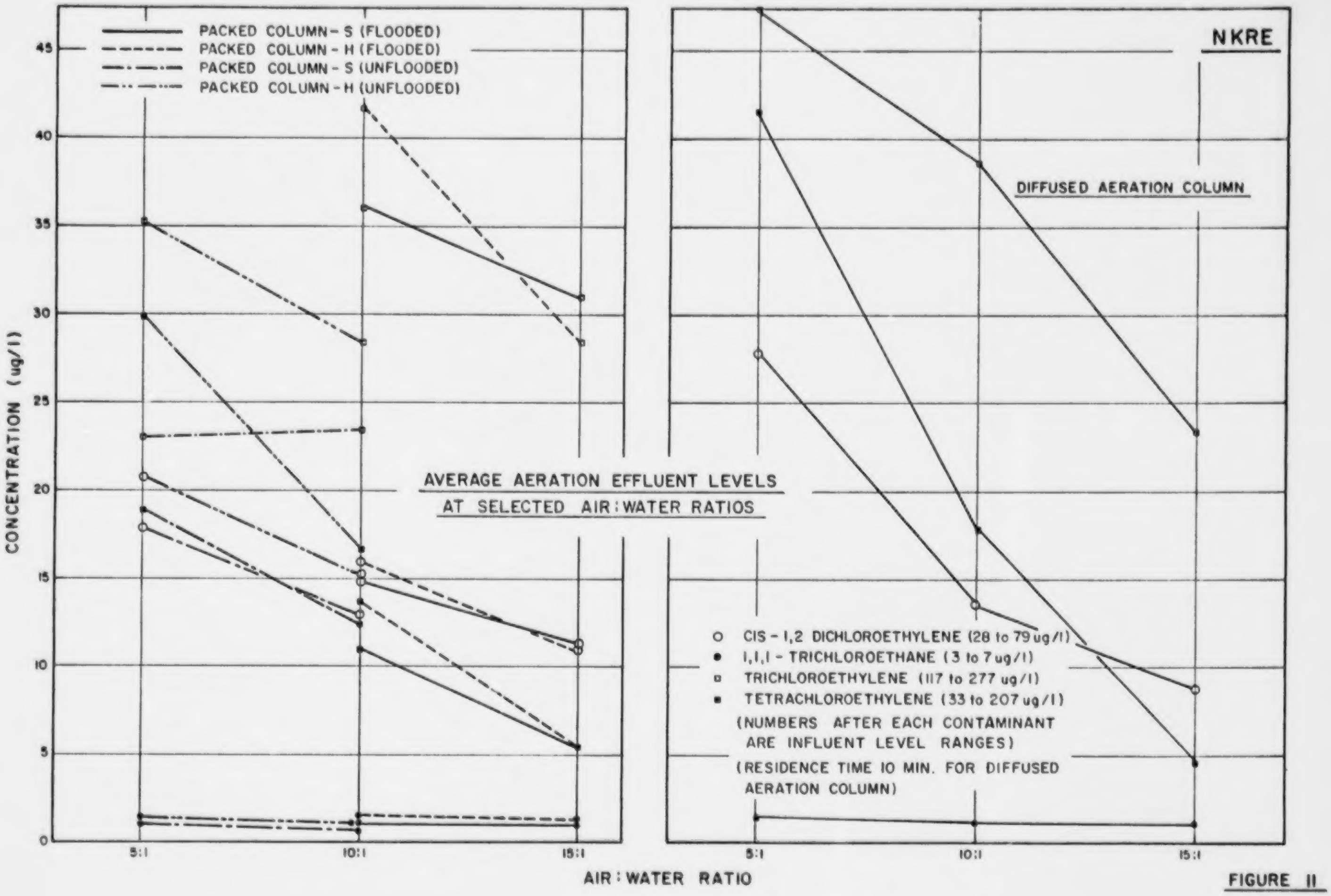
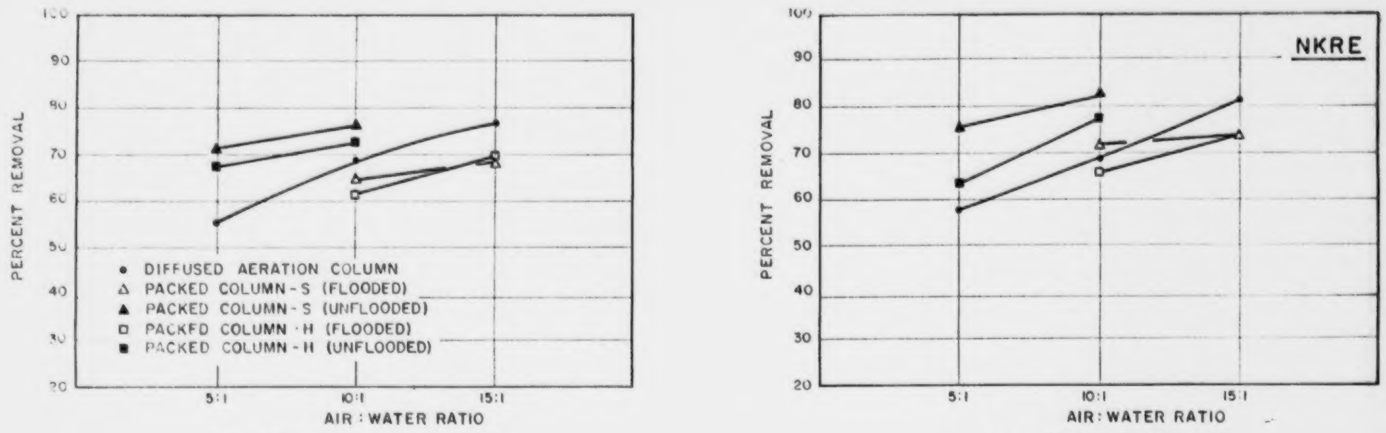

AVERAGE AERATION EFFLUENT LEVELS AT SELECTED AIR:WATER RATIOS

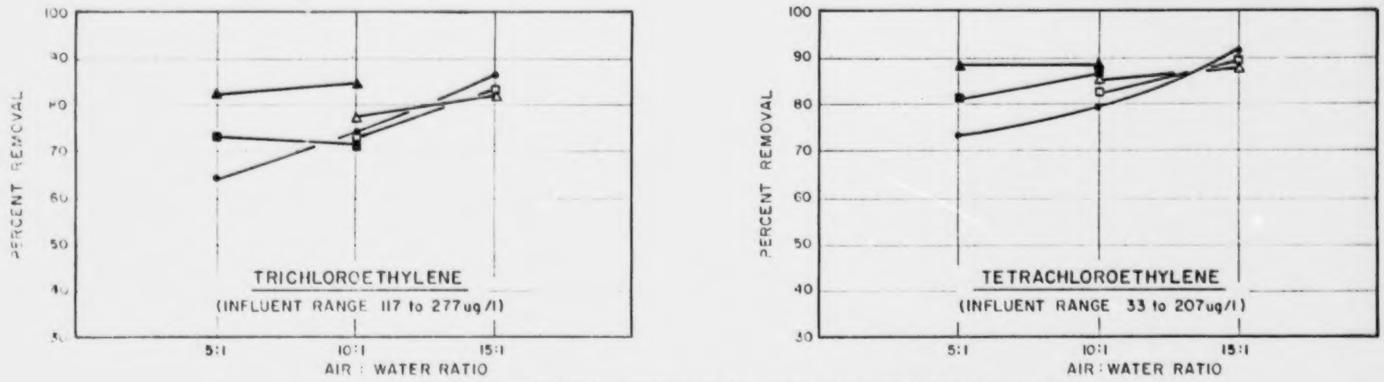
FIGURE II

34



CIS - 1,2 - DICHLOROETHYLENE
(INFLUENT RANGE 28 to 79 ug/l)

1,1,1 - TRICHLOROETHANE
(INFLUENT RANGE 3 to 7 ug/l)



AVERAGE PERCENT REMOVALS AT SELECTED AIR : WATER RATIOS

FIGURE 12

the columns. The segment of the graph between air to water ratios of 15:1 and 10:1 represents average effluent levels obtained when the columns were flooded. The average effluent levels obtained during the testing with the media unflooded or above water surface are presented by the other segment of the graph between air to water ratios of 10:1 and 5:1.

The effect of dropping the water level in the packed column can be seen more clearly in Table 4. The performance of the packed column under both air introduction systems, diffuser stones and hole, improved as the water level was dropped. Since all levels of water were tested only at the air to water ratio of 10:1, only the results of that air to water ratio are presented on Table 4. Since all conditions, except the water depth, remained constant for the 10:1 air to water ratio, the testing segment's change in efficiency is attributable to the operation of the packing above the water surface.

Figures 13 through 16 present influent and effluent levels achieved by the various aeration methods for each of the contaminants studied. Effluent, as well as influent, levels for 1,1,1 trichloroethane were well below the N.Y. State guideline level of 50 ug/l per contaminant. Aeration is seen to have reduced contaminants below present N.Y. State Guidelines for all air to water ratios most of the time. For a short period of time, at the latter part of testing using the 10:1 air to water ratio, trichloroethylene and tetrachloroethylene exceeded the N.Y. State Guidelines. The data for this period does not correspond to the remaining data and there is no apparent explanation. The overall test results indicate that aeration would produce water, using all tested air to water ratios, which would comply with N.Y. State Guidelines for over 98% of the time for all contaminants.

It is apparent from these figures and tables that the removal efficiency of all the systems was greatest for tetrachloroethylene, and the least efficient for cis-1,2-dichloroethylene. Overall average removal efficiencies, by contaminant, are presented below:

Contaminant	Overall Average % Removal
Tetrachloroethylene	84%
Trichloroethylene	77%
1,1,1-Trichloroethane	71%
cis-1,2-Dichloroethylene	67%

At the end of Phase II aeration testing the U.S. EPA (MERL-DWRD) requested NKRE to modify the aeration testing so that a mass transfer coefficient K_La could be determined.

TABLE 4

COMPARISON OF PACKED COLUMN PERFORMANCE (% REMOVAL) AT DIFFERENT WATER DEPTHS

Packed Column - Diffuser

Water Depth in Column*	CIS	1,1,1	TRI	TETRA	AVERAGE % REMOVAL
Full (8.0 ft Depth)	61	76	75	84	74
1.5' Above Packing (3.5 ft Depth)	66	78	80	88	78
Bottom of Packing (2.0 ft Depth)	76	82	84	88	80

Packed Column - Hole

Water Depth in Column*	CIS	1,1,1	TRI	TETRA	AVERAGE % REMOVAL
Full (8.0 ft Depth)	58	59	72	80	67
1.5' Above Packing (3.5 ft Depth)	64	78	75	84	75
Bottom of Packing (2.0 ft Depth)	73	78	81	86	79

---

* Air: Water Ratio = 10:1

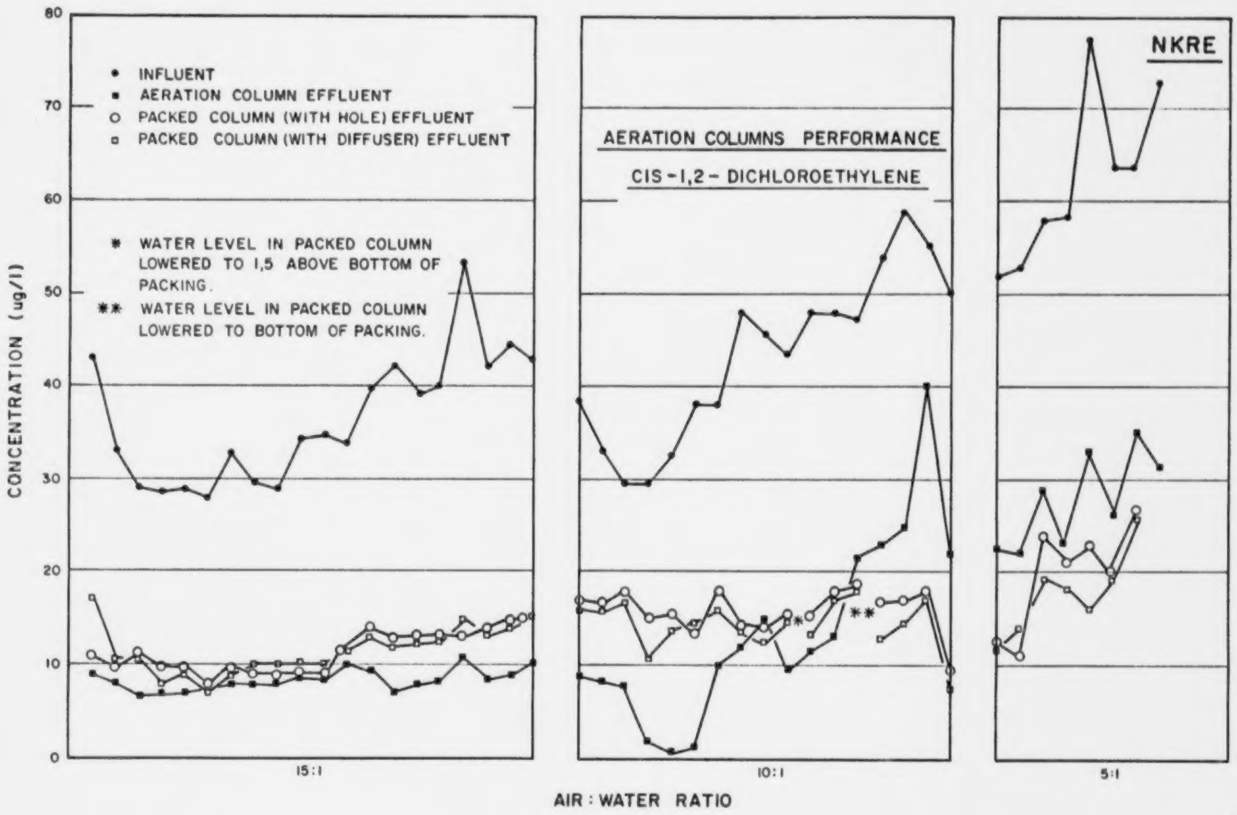

AERATION COLUMNS PERFORMANCE
CIS-1,2-DICHLOROETHYLENE
NKRE
● INFLUENT
■ AERATION COLUMN EFFLUENT
○ PACKED COLUMN (WITH HOLE) EFFLUENT
□ PACKED COLUMN (WITH DIFFUSER) EFFLUENT
* WATER LEVEL IN PACKED COLUMN LOWERED TO 1,5 ABOVE BOTTOM OF PACKING.
** WATER LEVEL IN PACKED COLUMN LOWERED TO BOTTOM OF PACKING.
CONCENTRATION (ug/l)
0
10
20
30
40
50
60
70
80
15:1
10:1
5:1
AIR : WATER RATIO

FIGURE 13

38

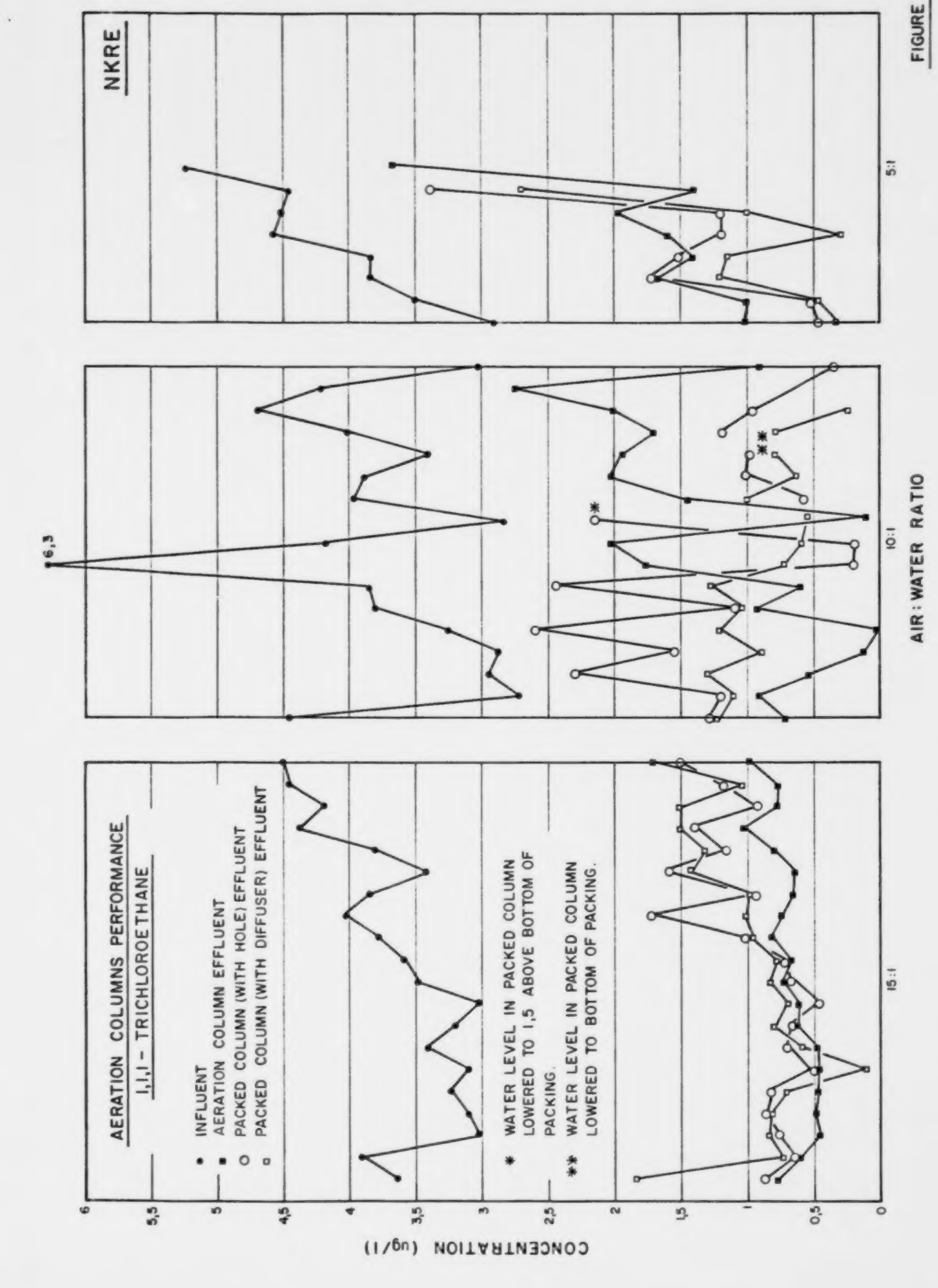

AERATION COLUMNS PERFORMANCE
1,1,1 - TRICHLOROETHANE
● INFLUENT
■ AERATION COLUMN EFFLUENT
○ PACKED COLUMN (WITH HOLE) EFFLUENT
□ PACKED COLUMN (WITH DIFFUSER) EFFLUENT
* WATER LEVEL IN PACKED COLUMN LOWERED TO 1,5 ABOVE BOTTOM OF PACKING.
** WATER LEVEL IN PACKED COLUMN LOWERED TO BOTTOM OF PACKING.
NKRE
6,3
CONCENTRATION (ug/l)
6
5,5
5
4,5
4
3,5
3
2,5
2
1,5
1
0,5
0
15:1
10:1
5:1
AIR : WATER RATIO

FIGURE 14

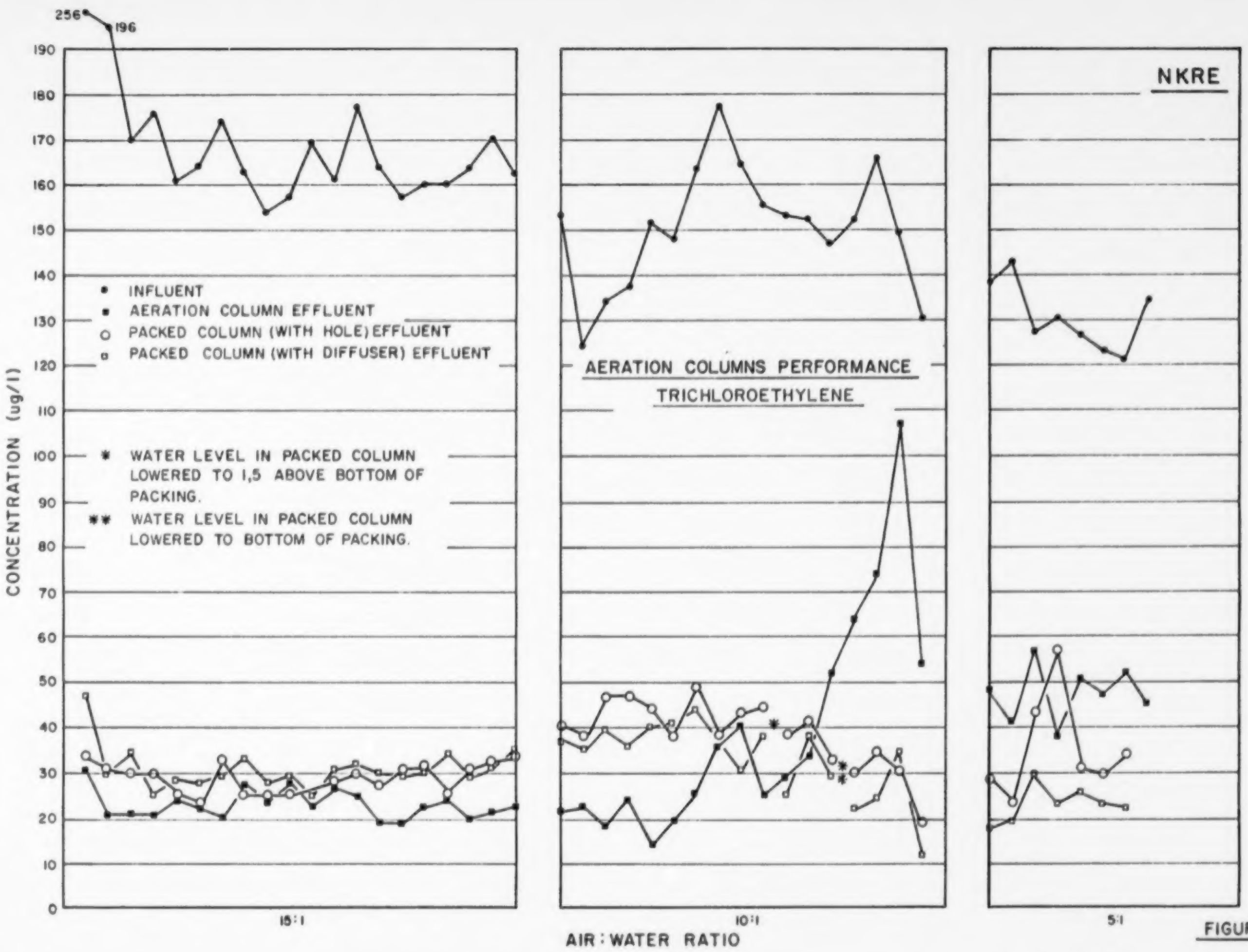

256
196
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
CONCENTRATION (ug/l)
• INFLUENT
▪ AERATION COLUMN EFFLUENT
○ PACKED COLUMN (WITH HOLE) EFFLUENT
▫ PACKED COLUMN (WITH DIFFUSER) EFFLUENT
* WATER LEVEL IN PACKED COLUMN LOWERED TO 1,5 ABOVE BOTTOM OF PACKING.
** WATER LEVEL IN PACKED COLUMN LOWERED TO BOTTOM OF PACKING.
AERATION COLUMNS PERFORMANCE
TRICHLOROETHYLENE
NKRE
15:1
10:1
5:1
AIR : WATER RATIO

FIGURE 15

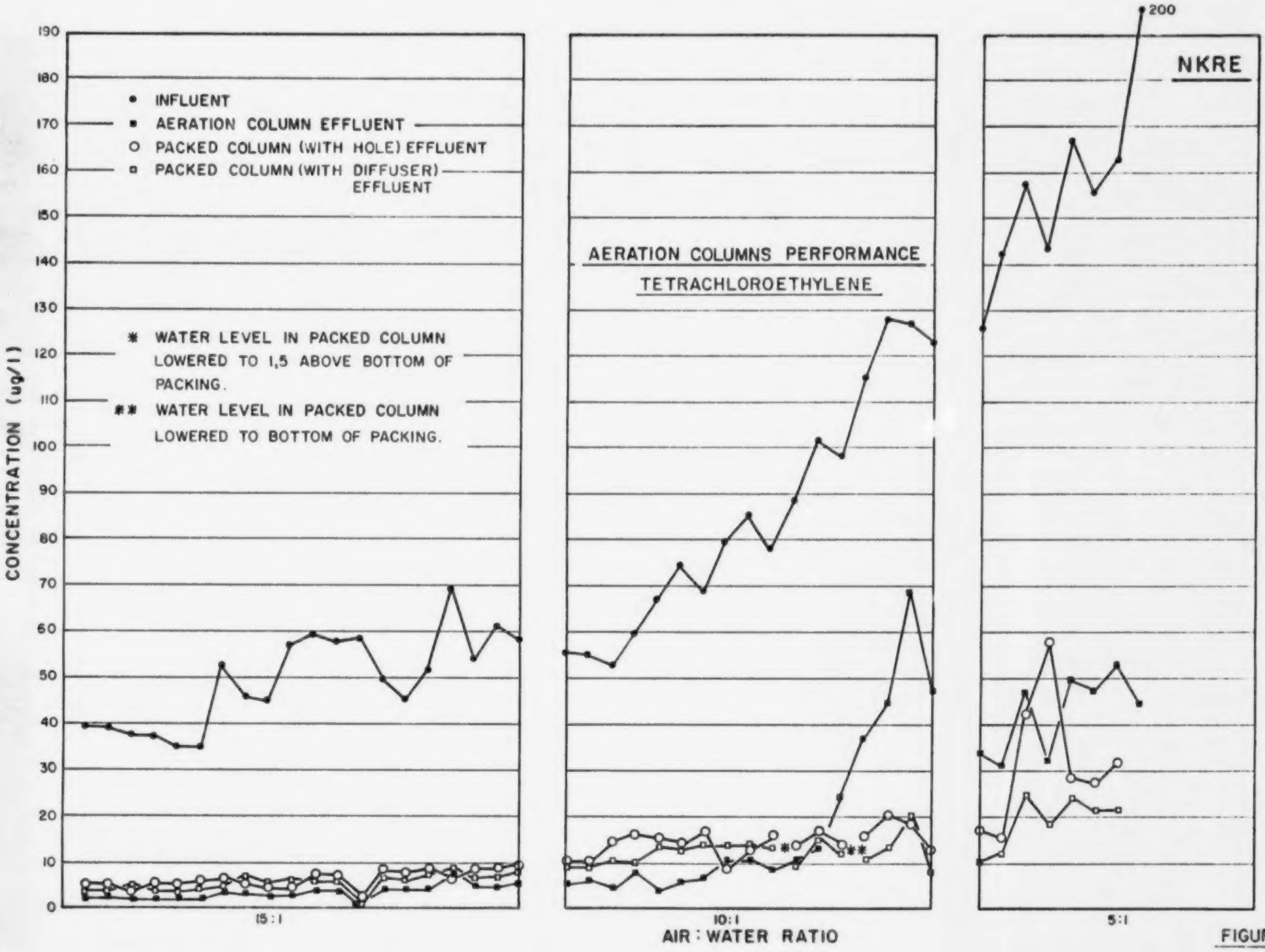

200
NKRE
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
CONCENTRATION (ug/l)
● INFLUENT
■ AERATION COLUMN EFFLUENT
○ PACKED COLUMN (WITH HOLE) EFFLUENT
□ PACKED COLUMN (WITH DIFFUSER) EFFLUENT
* WATER LEVEL IN PACKED COLUMN LOWERED TO 1,5 ABOVE BOTTOM OF PACKING.
** WATER LEVEL IN PACKED COLUMN LOWERED TO BOTTOM OF PACKING.
AERATION COLUMNS PERFORMANCE
TETRACHLOROETHYLENE
*
**
15:1
10:1
5:1
AIR : WATER RATIO

FIGURE 16

This was accomplished by removing the packing from the second aeration column and passing the water through both columns in series utilizing identical air to water ratios in each column.

The results of the testing system designed to determine the oxygen mass transfer coefficient, K_La, are presented in Table 5. The K_La was computed using the following formula:

$$K_La = \frac{\ln(C^*-C_1)-\ln(C^*-C_2)}{t_2-t_1}$$

Where C^* = equilibrium DO saturation concentration

C_1 = DO concentration at time t_1 (influent)

C_2 = DO concentration at time t_2 (effluent)

The mass transfer coefficient was calculated for the influent and effluent from column I (10 minutes aeration time); for the influent and effluent from column II (10 minutes aeration time); and for the influent to column I and the effluent from column II, which were operated in series (20 minutes aeration time). The air to water ratio ranged from 5:1 to 17:1.

Figure 17 is a presentation of the average K_La for the two columns individually and for the combined system vs. the air to water ratio. This illustrates that the K_La increased with an increasing air to water ratio.

Also presented on Figure 17 is the average K_La after 10 minutes and after 20 minutes of aeration time for each air to water ratio tested. This illustrates that K_La decreased with increased aeration time.

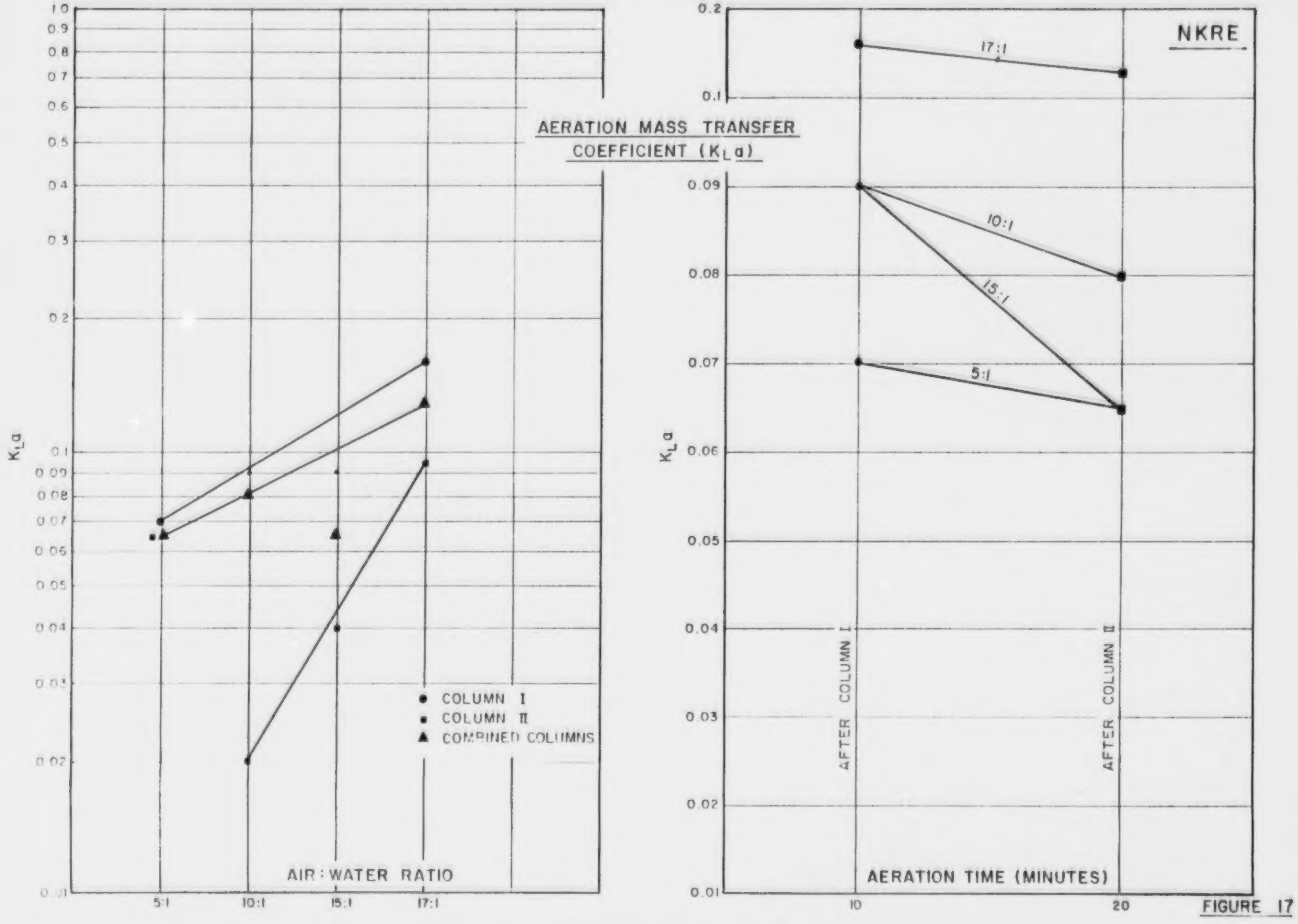
It can be concluded, therefore, that a relatively high K_La is more dependent on the air to water ratio than on the aeration period.

It would seem logical that the percent removal of the specific organic contaminants would be directly related to the K_La. However, the data presented on Table 6 indicates that this is true only for the combined system, where the highest percent removal corresponded to the highest K_La. The data from column I and column II does not show such a correlation.

TABLE 5

AERATION TESTING TO DETERMINE MASS TRANSFER COEFFICIENT

Air: Water Ratio	Source	Water Temp. (°C)	D.O. (mg/l)	Air Temp. (°C)	cis (ug/l)	1,1,1 (ug/l)	Tri (ug/l)	Tetra (ug/l)
Date:	January 28, 1981							
17:1	Inf.	13.5	7.5	8.0	100	6.3	151	219
	1st Col. Eff.	13.5	10.0		35.4	2.4	45.2	47.9
	2nd Col. Eff.	12.5	10.4		6.7	0.1	15.0	12.4
15:1	Inf.	13.5	7.2	7.5	89.3	6.2	141	207
	1st Col. Eff.	13.0	9.3		25.8	1.1	31.4	35.1
	2nd Col. Eff.	13.0	9.6		8.4	0.3	26.0	21.3
10:1	Inf.	13.5	7.2	7.0	96.3	6.2	145	214
	1st Col. Eff.	13.0	9.2		23.8	0.9	29.5	28.2
	2nd Col. Eff.	13.0	9.7		8.7	0.4	11.3	9.1
5:1	Inf.	13.5	7.4	7.0	90.2	5.7	137	199
	1st Col. Eff.	14.0	8.8		26.1	0.5	34.3	34.2
	2nd Col. Eff.	14.0	9.4		19.0	0.7	22.5	19.7
Date:	January 29, 1981							
17:1	Inf.	13.5	7.4	3.0	88.5	5.7	141	207
	1st Col. Eff.	13.0	9.8		26.3	1.2	26.5	34.8
	2nd Col. Eff.	13.0	10.4		1.7	N.O.	4.1	2.0
15:1	Inf.	13.0	7.6	3.0	89.9	5.8	139	204
	1st Col. Eff.	13.0	9.4		18.7	0.7	22.4	23.2
	2nd Col. Eff.	13.5	9.8		11.5	0.0	14.7	8.1
10:1	Inf.	13.5	7.9	5.0	90.9	5.9	146	204
	1st Col. Eff.	13.5	9.4		39.8	1.4	56.3	58.8
	2nd Col. Eff.	13.5	10.1		11.5	0.4	10.0	8.7
5:1	Inf.	14.0	8.2	5.0	103	6.3	155	218
	1st Col. Eff.	13.5	9.4		33.8	1.5	44.7	46.0
	2nd Col. Eff.	13.5	10.0		20.7	1.0	20.7	19.0



AERATION MASS TRANSFER COEFFICIENT (K_La)

FIGURE 17

TABLE 6

ORGANIC CONTAMINANT PERCENT REMOVAL

(During K_La Testing)

COLUMN	AIR:WATER RATIO	K_La	TOTAL ORGANIC CONTAMINANT % REMOVAL
1	5:1	.07	76.0
	10:1	.09	73.6
	15:1	.09	82.1
	17:1	.16	76.2
2	5:1	.065	43.1
	10:1	.02	72.1
	15:1	.04	43.9
	17:1	.095	82.5
Combined	5:1	.065	86.5
	10:1	.08	93.3
	15:1	.065	89.9
	17:1	.13	95.5

OTHER CONTAMINANTS

Besides the compounds described in this report, other peaks were observed in the analysis of the well water. No samples were analyzed by gas chromatography - mass spectroscopy (GCMS), which would positively identify what these contaminants are. That they are halogenated is apparent; they would not be detected otherwise. A few samples were analyzed by the U.S. EPA-MERL, and based solely on the retention times of these compounds compared with those in the gas chromatograph's computer memory, the presence of the following compounds were reported: 1,1-dichloroethylene, 1,1-dichloroethane and 1,2-dichloroethane. (See Memorandum in Appendix D.)

While the retention time is characteristic of a certain compound, provided the analytical procedure remains the same, it should be noted that more than one compound may have the same retention time. Moreover, one must allow a certain tolerance, variation from the accepted figure, and the wider this variation, the more compounds that can fit.

Before the results from U.S. EPA-MERL were known, an attempt was made to determine whether other particular compounds were present. Since the column utilized in the G.C. at the Glen Cove site could not separate the other compounds properly, determination of the other contaminants was not possible.

SECTION 7

REGENERATION

ADSORPTION STUDIES - RESIN

While the performance of Ambersorb XE-340 was shown in Phase I to be an effective adsorbent of the organic contaminants present in Well 22 water, its cost effectiveness rests on its ability to be regenerated. The attempts at regeneration in Phase I proved, at best, to be only partially successful. Considerable improvements, described in Section 4, were made to enhance the degree of regeneration. The actual performance of the regeneration followed the pattern described in the Phase I report. Figures 18 through 29 present influent and effluent levels both before and after regeneration(s).

At the beginning of Phase II, Column V, which contained resin used throughout Phase I, was regenerated. It was operated under the same conditions as Column IV, thus giving an initial basis for comparing this resin, regenerated with the new equipment, with the virgin resin. A direct comparison of the effluents shows that column IV has slightly lower contaminant levels throughout the first cycle (see Figures 5 through 8). Both columns were ready for regeneration at the same time and were steam-stripped in succession.

Actual performance is the measure of success of a regeneration, which takes a considerable time to evaluate. A more rapid determination of the degree of success is the calculation of the percent regeneration or percent of organics removed after being loaded on the media. This entails determining the amount of organics which have been removed from the resin during steam-stripping and comparing this total with the mass of contaminants removed by the resin from the water. The calculation of the loading requires only the summation of the differences in total contaminants between influent and effluent at each sampling, averaged over the interval between successive samplings; the amount of contaminants removed by steam regeneration is a simple determination of the contaminants present in the steam condensate multiplied by the amount of steam condensate utilized for the regeneration.

Even though this appears to be a simple calculation and monitoring of the condensate was made as closely as possible,

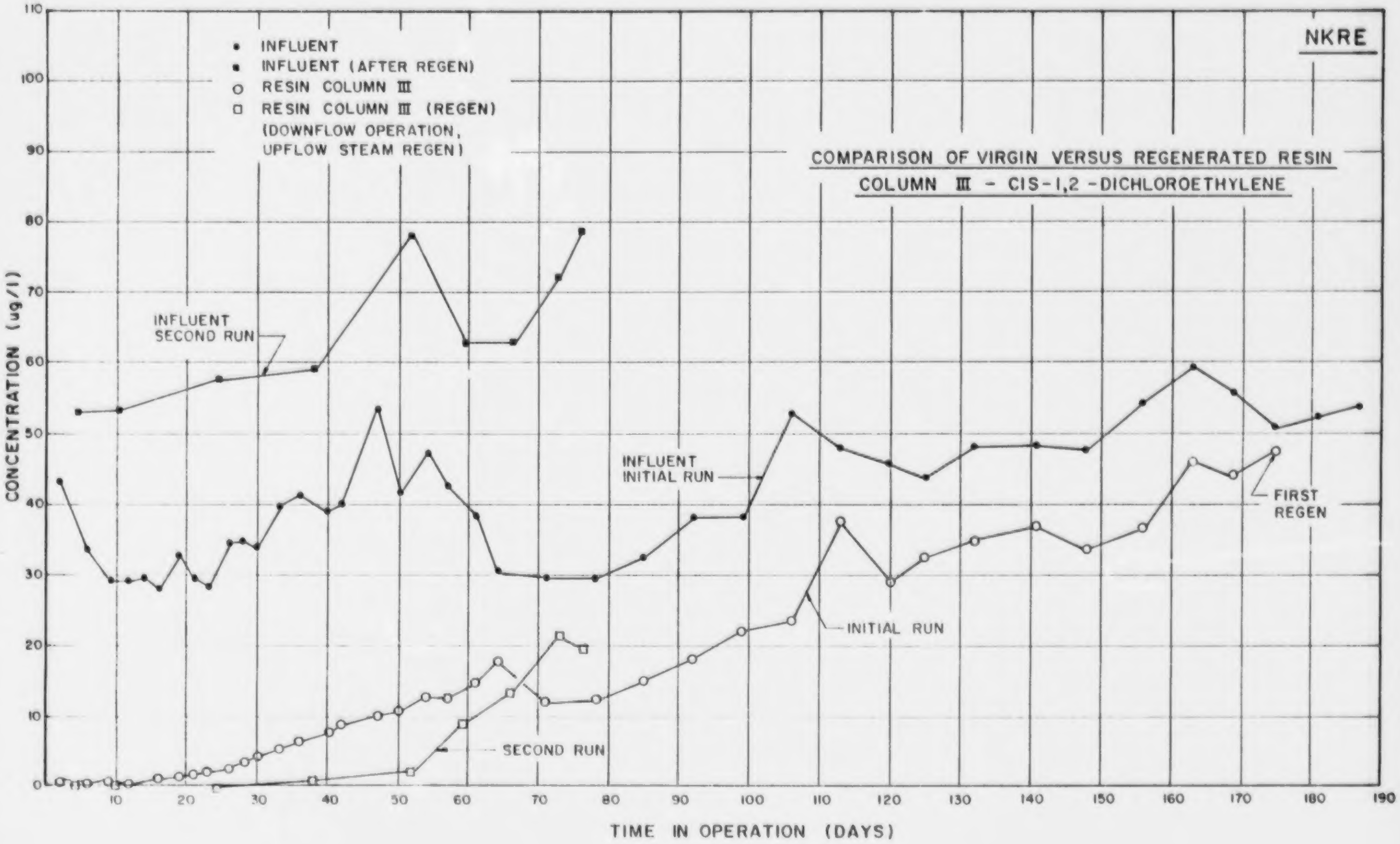
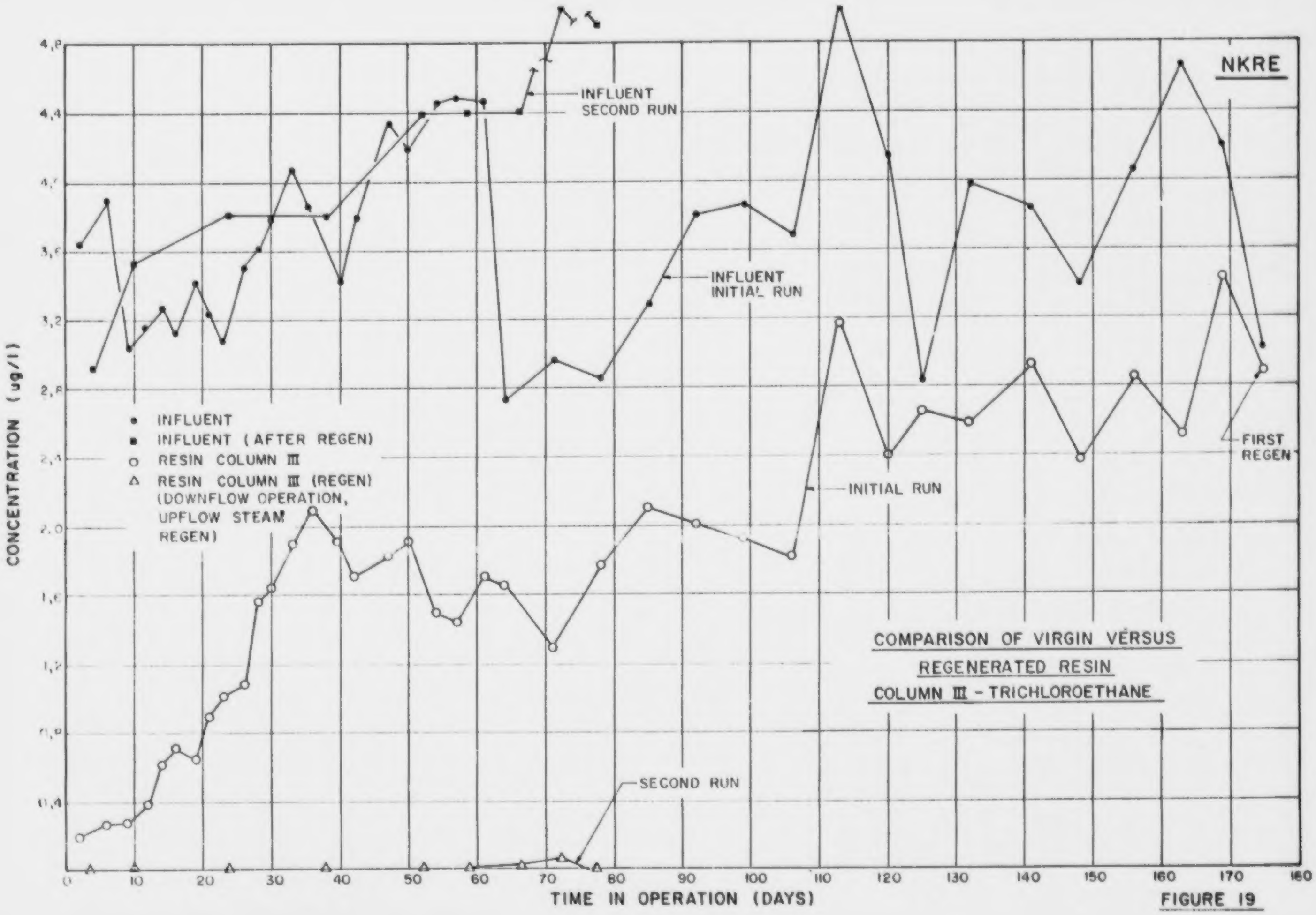

NKRE
COMPARISON OF VIRGIN VERSUS REGENERATED RESIN
COLUMN III - CIS-1,2-DICHLOROETHYLENE
● INFLUENT
■ INFLUENT (AFTER REGEN)
○ RESIN COLUMN III
□ RESIN COLUMN III (REGEN) (DOWNFLOW OPERATION, UPFLOW STEAM REGEN)
INFLUENT SECOND RUN
INFLUENT INITIAL RUN
FIRST REGEN
INITIAL RUN
SECOND RUN
CONCENTRATION (ug/l)
0
10
20
30
40
50
60
70
80
90
100
110
TIME IN OPERATION (DAYS)
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190

FIGURE 18



COMPARISON OF VIRGIN VERSUS
REGENERATED RESIN
COLUMN III - TRICHLOROETHANE

FIGURE 19

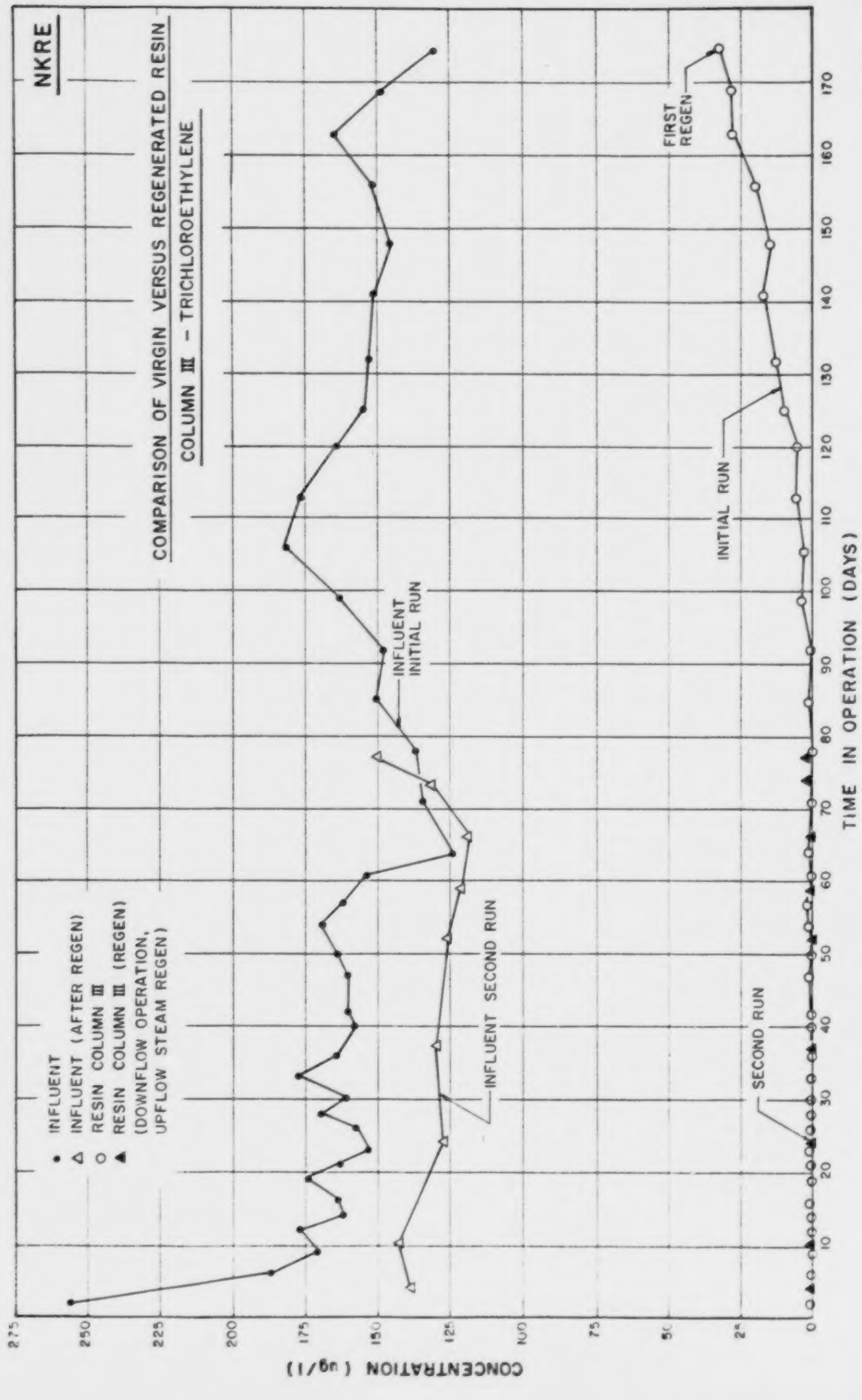

NKRE
COMPARISON OF VIRGIN VERSUS REGENERATED RESIN
COLUMN III - TRICHLOROETHYLENE
● INFLUENT
△ INFLUENT (AFTER REGEN)
○ RESIN COLUMN III
▲ RESIN COLUMN III (REGEN)
(DOWNFLOW OPERATION, UPFLOW STEAM REGEN)
INFLUENT INITIAL RUN
INFLUENT SECOND RUN
INITIAL RUN
SECOND RUN
FIRST REGEN
CONCENTRATION (ug/l)
0
25
50
75
100
125
150
175
200
225
250
275
TIME IN OPERATION (DAYS)
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170

FIGURE 20

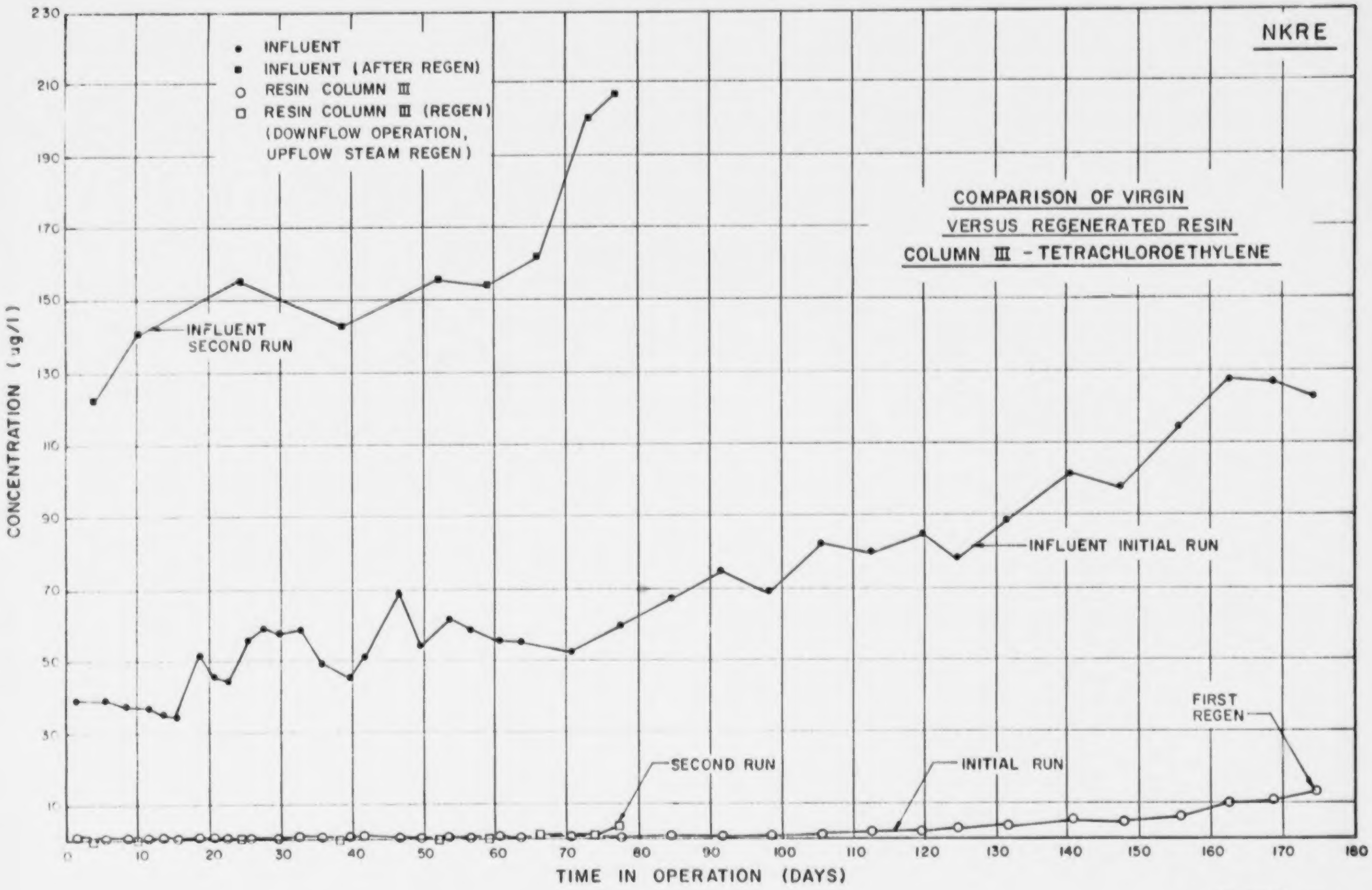
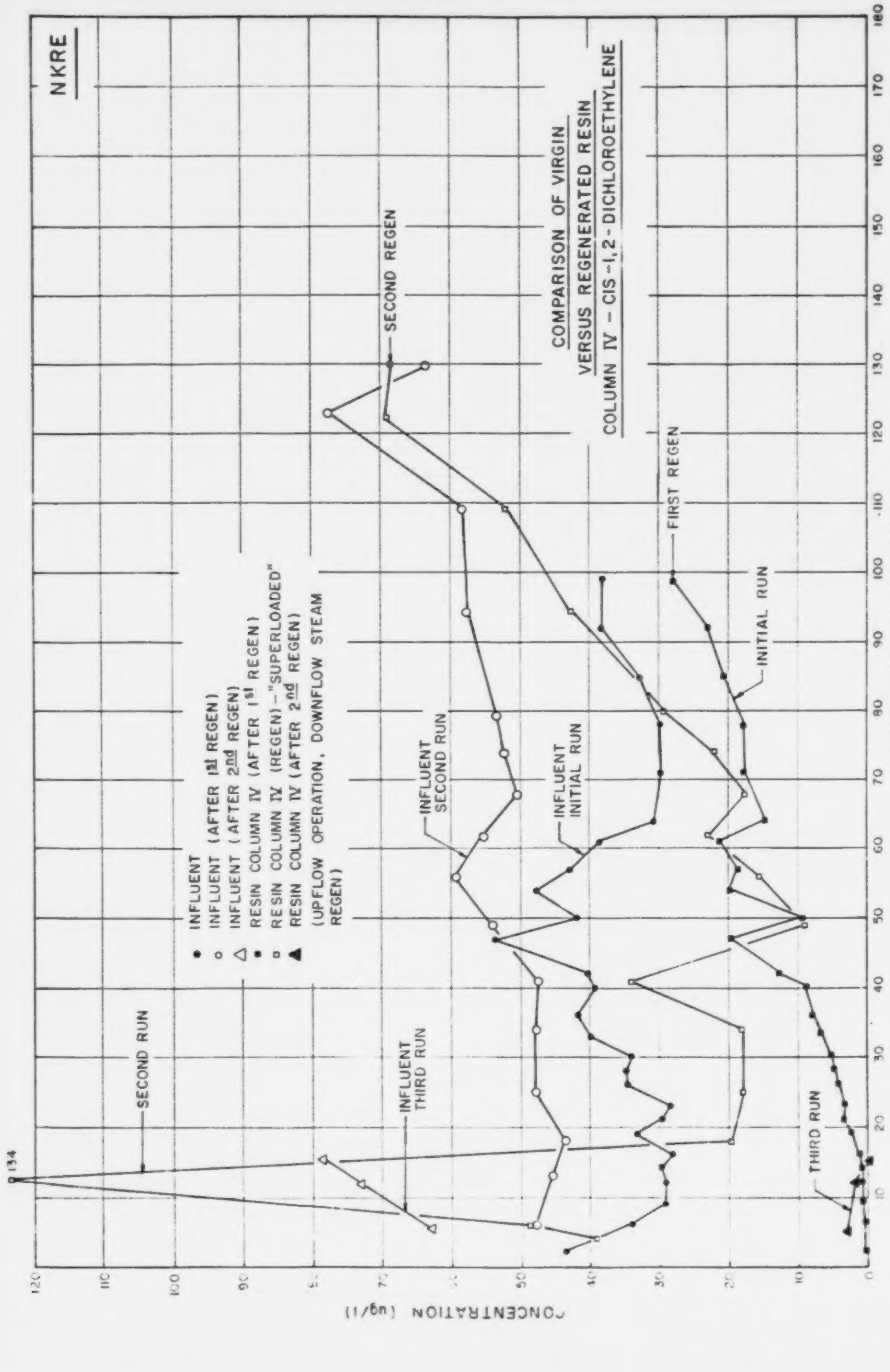
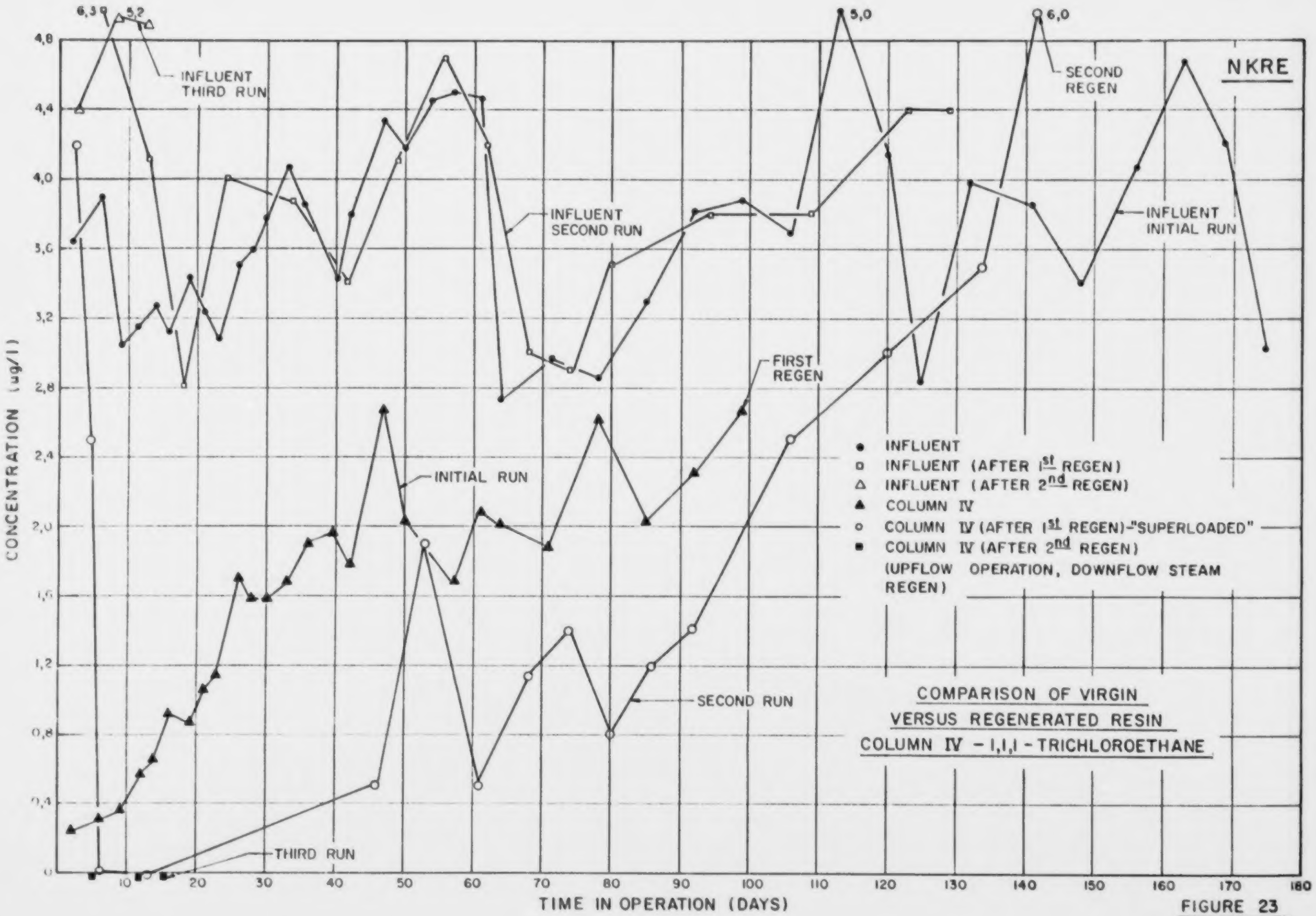

NKRE
COMPARISON OF VIRGIN
VERSUS REGENERATED RESIN
COLUMN III - TETRACHLOROETHYLENE
● INFLUENT
■ INFLUENT (AFTER REGEN)
○ RESIN COLUMN III
□ RESIN COLUMN III (REGEN)
(DOWNFLOW OPERATION,
UPFLOW STEAM REGEN)
INFLUENT
SECOND RUN
INFLUENT INITIAL RUN
SECOND RUN
INITIAL RUN
FIRST
REGEN
CONCENTRATION (μg/l)
230
210
190
170
150
130
110
90
70
50
30
10
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
TIME IN OPERATION (DAYS)

FIGURE 21



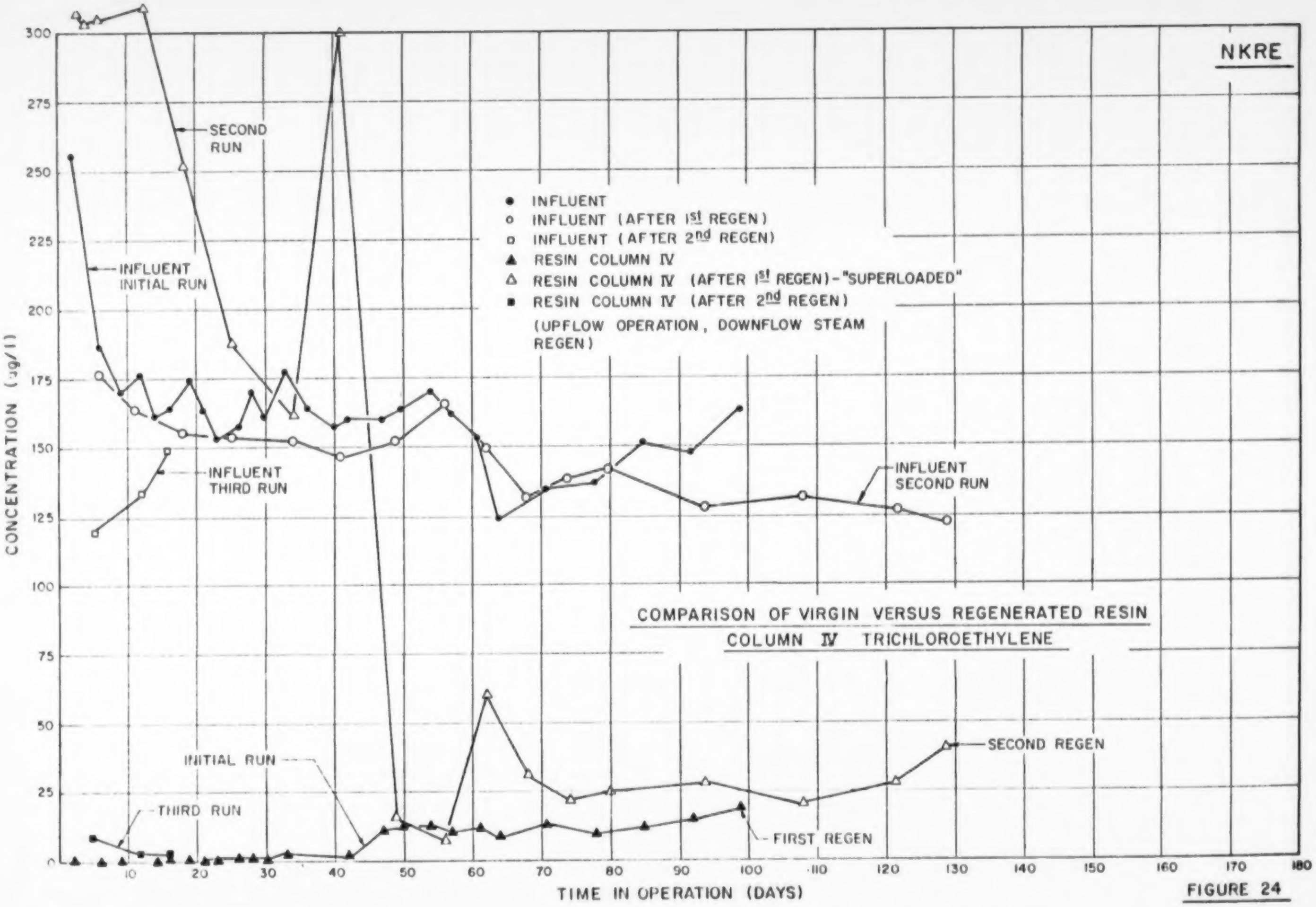
COMPARISON OF VIRGIN VERSUS REGENERATED RESIN
COLUMN IV - CIS-1,2-DICHLOROETHYLENE

FIGURE 22



COMPARISON OF VIRGIN VERSUS REGENERATED RESIN COLUMN IV - 1,1,1 - TRICHLOROETHANE

FIGURE 23



COMPARISON OF VIRGIN VERSUS REGENERATED RESIN
COLUMN IV TRICHLOROETHYLENE

FIGURE 24

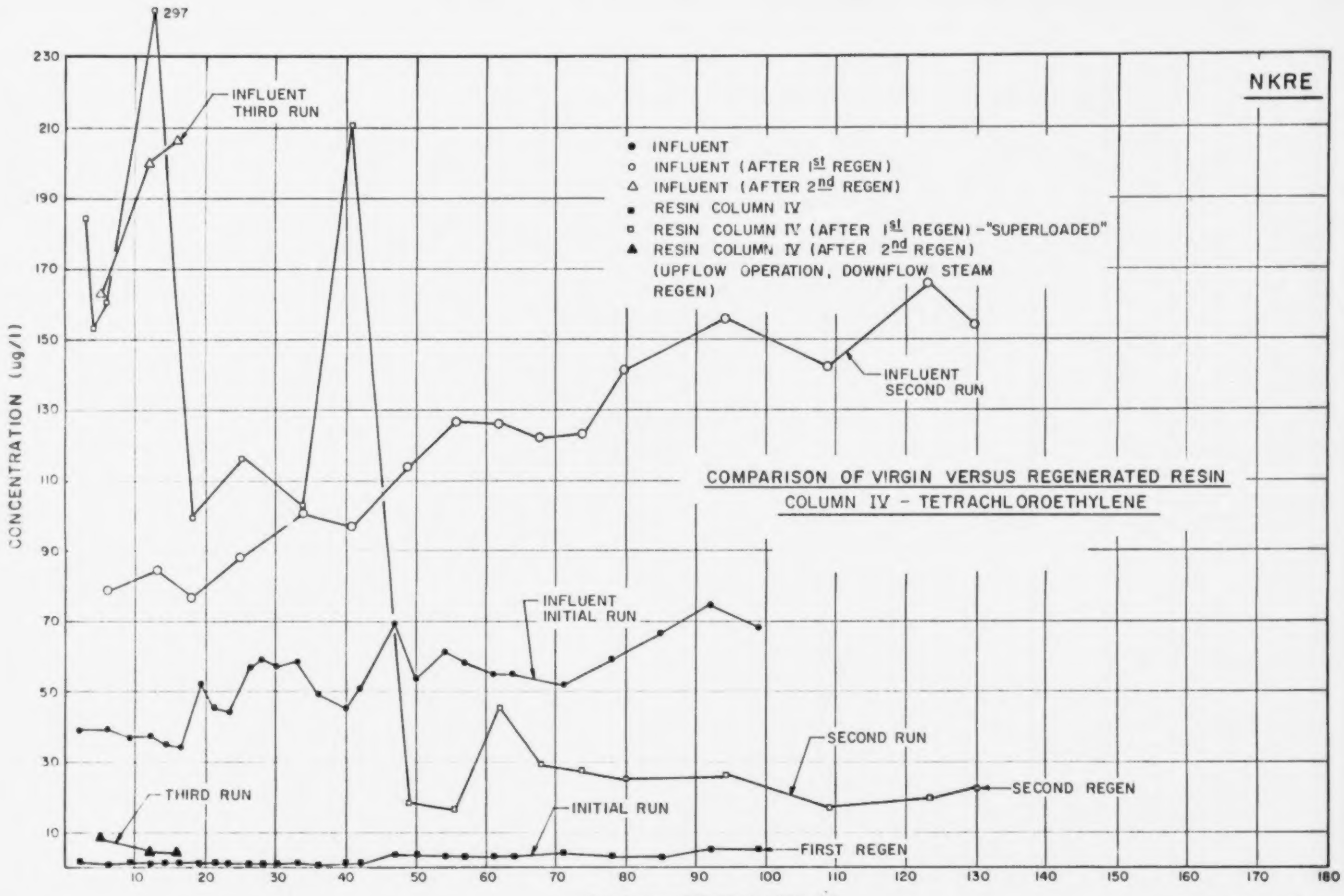
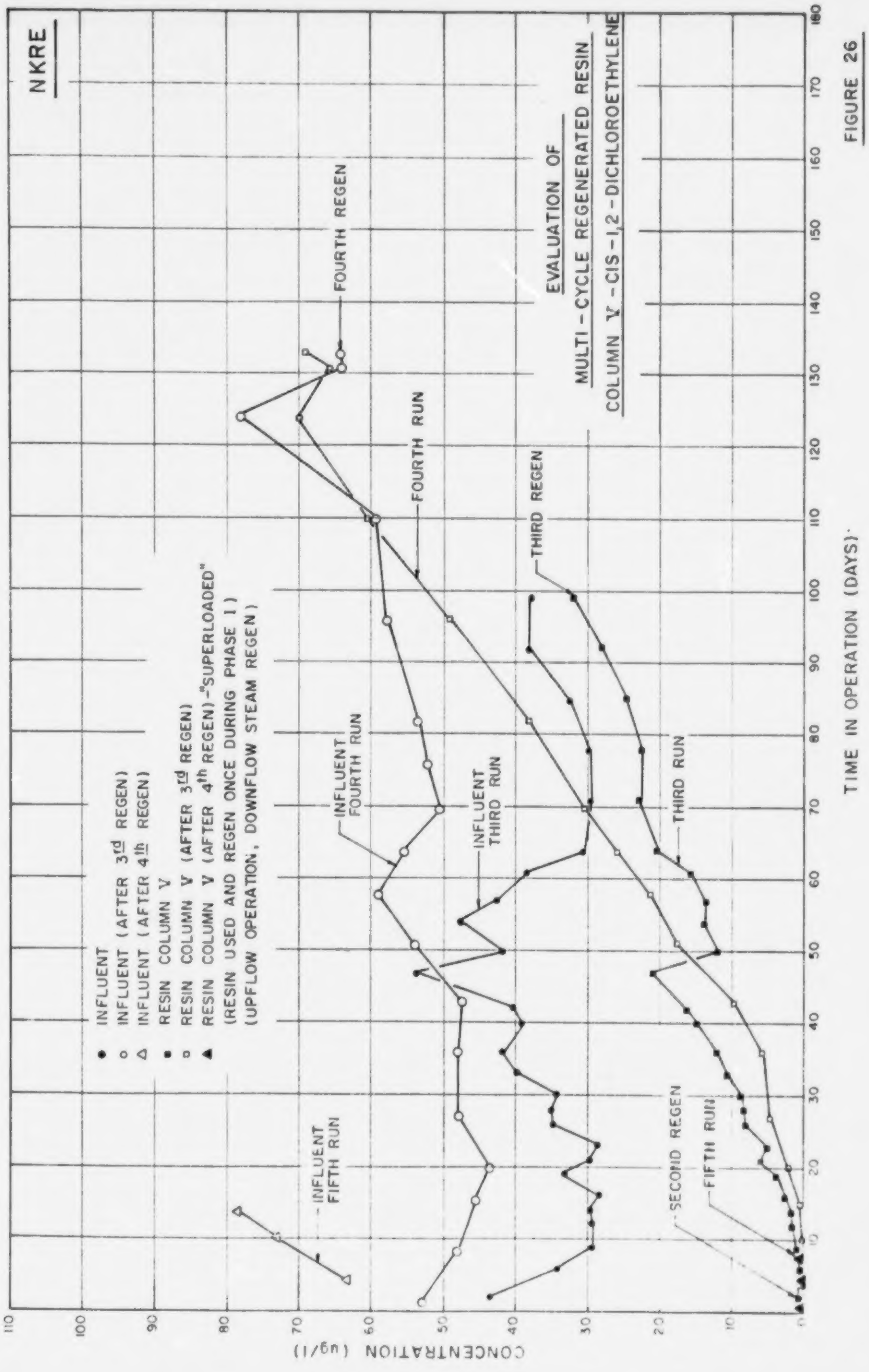
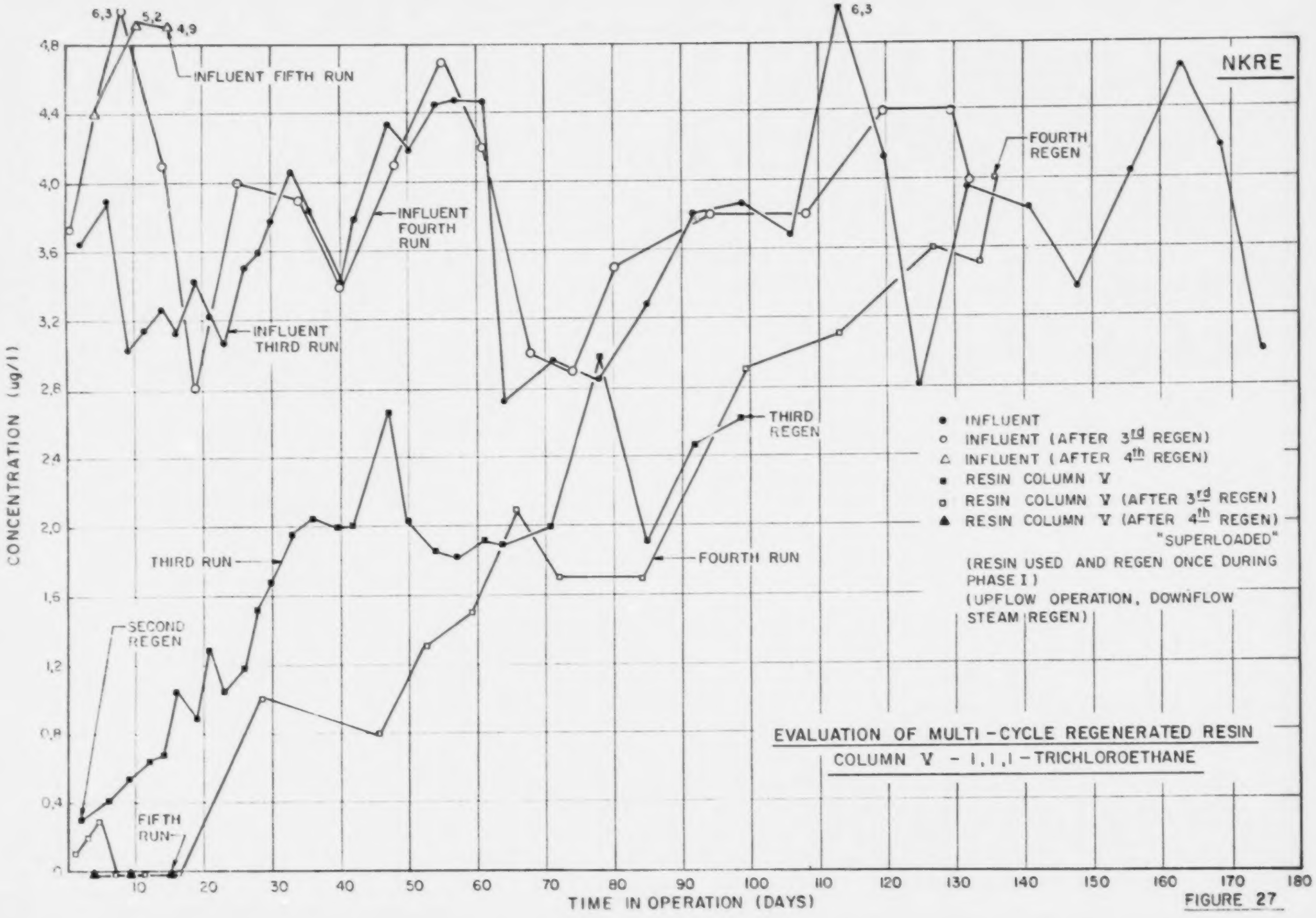

NKRE
COMPARISON OF VIRGIN VERSUS REGENERATED RESIN
COLUMN IV - TETRACHLOROETHYLENE
● INFLUENT
○ INFLUENT (AFTER 1st REGEN)
△ INFLUENT (AFTER 2nd REGEN)
■ RESIN COLUMN IV
□ RESIN COLUMN IV (AFTER 1st REGEN) - "SUPERLOADED"
▲ RESIN COLUMN IV (AFTER 2nd REGEN)
(UPFLOW OPERATION, DOWNFLOW STEAM REGEN)
297
INFLUENT THIRD RUN
INFLUENT SECOND RUN
INFLUENT INITIAL RUN
SECOND RUN
SECOND REGEN
THIRD RUN
INITIAL RUN
FIRST REGEN
CONCENTRATION (ug/l)
230
210
190
170
150
130
110
90
70
50
30
10
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
TIME IN OPERATION (DAYS)

FIGURE 25



EVALUATION OF
MULTI-CYCLE REGENERATED RESIN
COLUMN V - CIS-1,2-DICHLOROETHYLENE

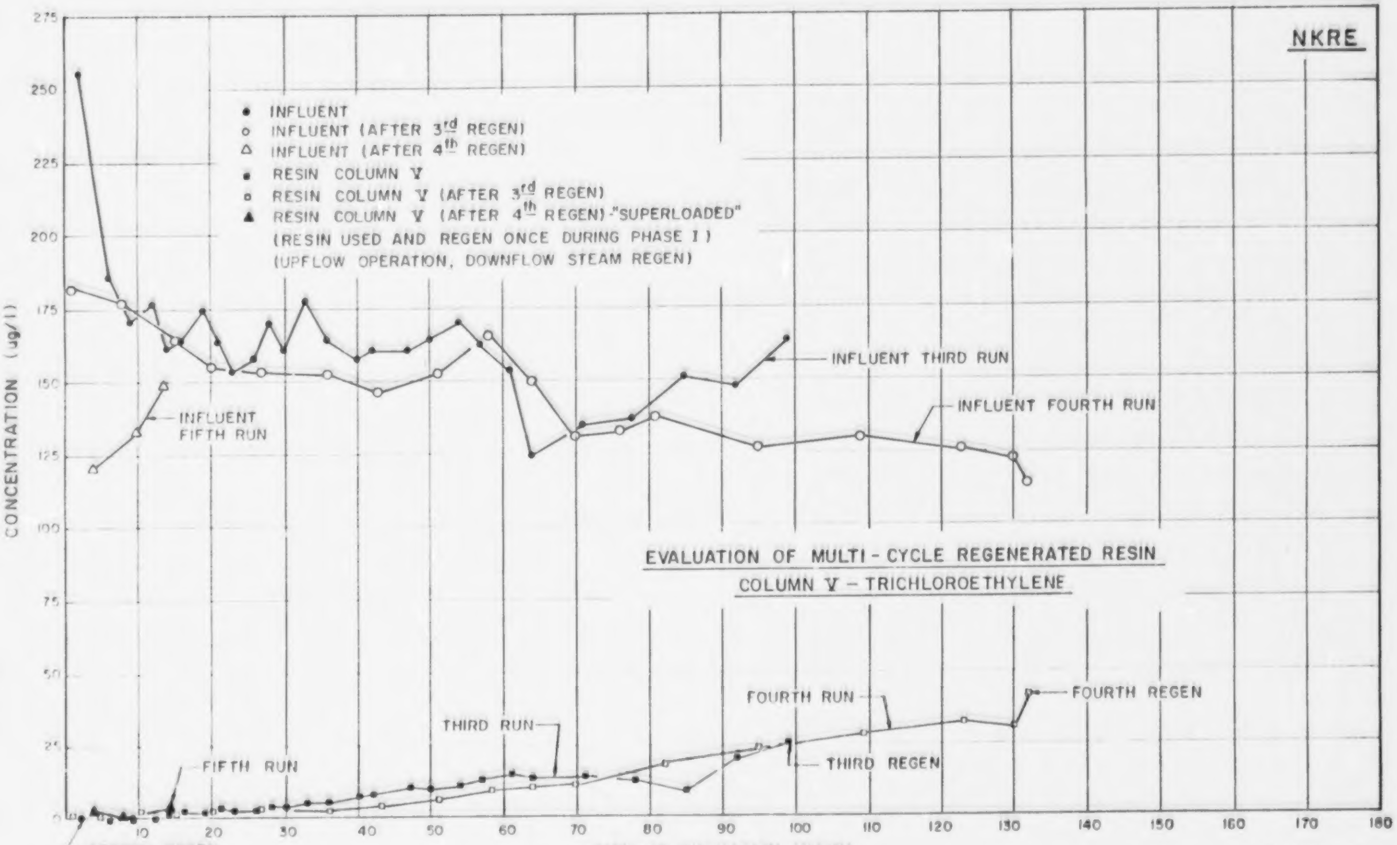
FIGURE 26



EVALUATION OF MULTI-CYCLE REGENERATED RESIN

COLUMN V - 1,1,1-TRICHLOROETHANE

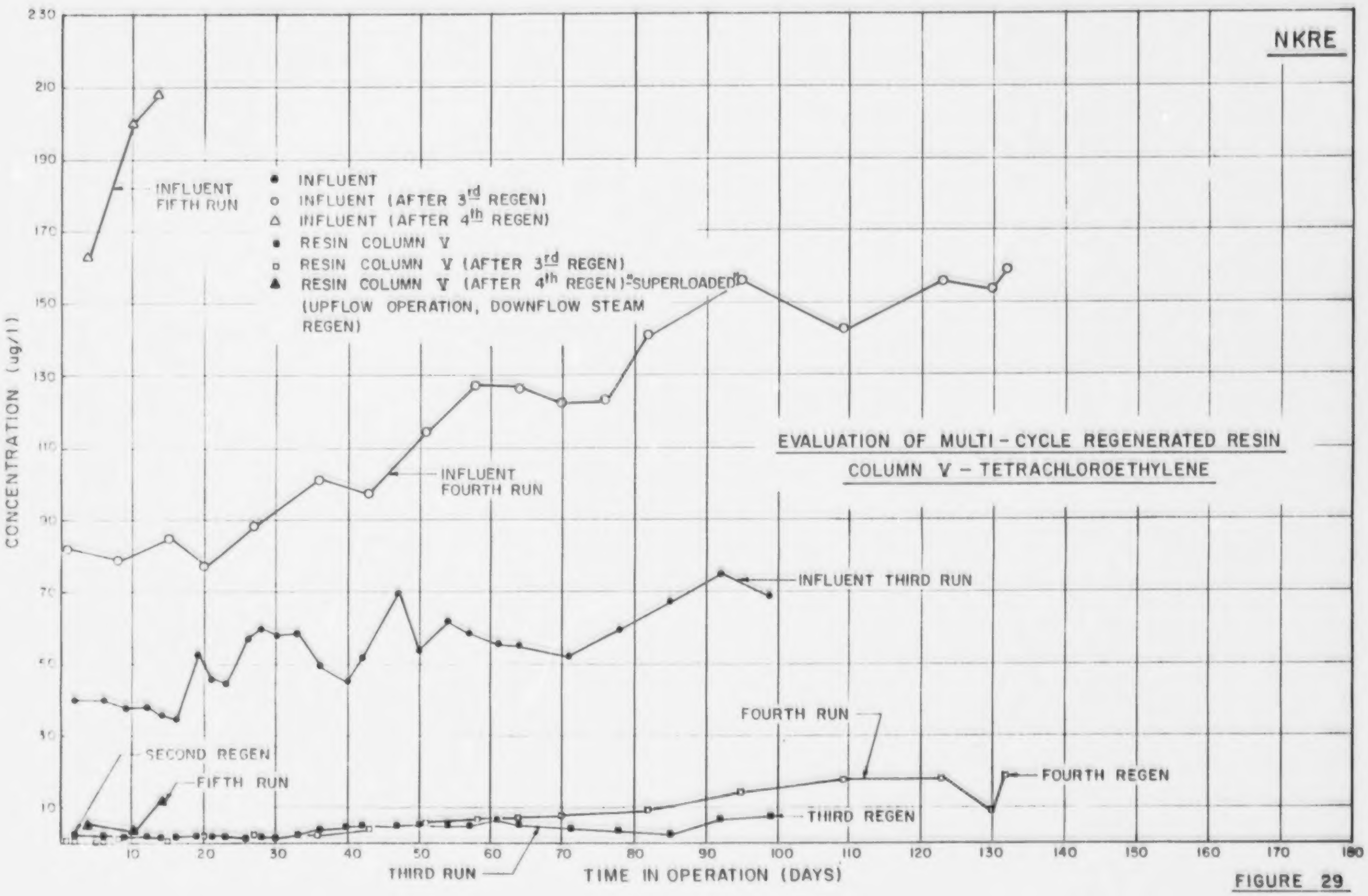
FIGURE 27



EVALUATION OF MULTI-CYCLE REGENERATED RESIN

COLUMN V - TRICHLOROETHYLENE

FIGURE 28



EVALUATION OF MULTI - CYCLE REGENERATED RESIN

COLUMN V - TETRACHLOROETHYLENE

FIGURE 29

accurate calculations without some assumptions were not possible. The problem is caused by the success of the process, i.e., proper steam-stripping will cause the first few bed volumes of steam which are condensed to contain such high concentrations of organics, that some do not dissolve in the condensed steam and a phase separation occurs. It is these two-phase systems which are difficult to analyze properly.

The aqueous phase presents no problems. However, the determination of the organics in the nonaqueous phase is troublesome, because the analytical equipment cannot tolerate such high concentrations of organics. It would make the G.C. unusable for several days, if not requiring parts replacement, and therefore requires a series of dilutions to reach a proper attenuation which introduces error possibilities. But more than this is the problem of measuring the volume of the nonaqueous phase because the total separation of the small organic layer from the large volume of the aqueous phase is not easily affected. Complicating the situation is the formation of a third phase, yet to be identified. At first, it was thought that this may comprise inorganic salts; however, palpation showed it to be a solid. It may be a suspension of organics in water; however, this was not confirmed.

The determination of the amount of contaminants in nonaqueous phases becomes guesswork, at best. As these form the majority of organics removed, figures for percentage regeneration must be looked upon as only approximations. The computed data from all regenerations is presented on Table 7 and indicates that generally high percentages of organics were removed for each regeneration returning the resin to a reusable state.

Figures 26 through 29 show the graphical plot of the influent and effluent data for all runs of Column V during Phase II. A comparison of the results on these figures shows that for 1,1,1-trichloroethane, the two cycles are remarkably similar, although the second cycle is lower than the first; and for trichloroethylene, the results are close, with the second cycle being better from day 30-75 and the first cycle better for days 75-95. The influents for the second cycle were considerably higher in cis-1,2-dichloroethylene and tetrachloroethylene. Therefore, it is not surprising that the first cycle effluents, in general, were lower in these contaminants. Yet, for cis-dichloroethylene, the second cycle effluent was lower for almost the first fifty days.

Another regeneration was done on Column V resin. This was done with "superloading," which shall be described directly. The data for the few samples taken after this are also shown in Figures 26 through 29.

TABLE 7

SUMMARY OF REGENERATION - RESIN COLUMNS

	Column III	Column IV	Column V	Data on Phase I Regeneration of Resin Used in Column V During Phase II
Composition	Rohm & Haas Ambersorb XE-340 virgin	Rohm & Haas Ambersorb XE-340 virgin	Rohm & Haas Ambersorb XE-340 regenerated	
Resin Bed Volume (liters)	5	5	5	5
Direction of Water Flow	Down	Up	Up	-
Direction of Steam	Up	Down	Down	Down
Regeneration	First	First	Third	First
Dates	11/2-11/14/80	9/4-9/5/80	9/2-9/3-80	10/30-11/2/79
Calculated Bed Volumes of Water Passed until Regeneration	135,118	76,438	76,438	67,278
Bed Volume of Steam Used	25 ½	23	30	67
Loading - Carryover (g)*	-	-	19.2	-
Organics in Water (g)**	126.2	79.0	79.1	92.8
Superloading (g)***	-	22.8	-	-
Total Loading (g)	126.2	101.8	98.3	92.8
Organics Removed - Aqueous Phase (g)	35.9	42.5	38.7	81.9
Estimated Volume - Organic Phase (ml)	67	45	1	0
Mass of Organic Phase (g)	100.5	67.5	1.5	0
Total Removed (g)	136.4	110.0	40.2	81.9
Organics Remaining (g)	0	0	58.1	10.9
Percentage Regeneration****	108%	108%	41%	88%
Regeneration		Second	Fourth	Second
Dates		1/13-1/14/81	1/14-1/15/81	5/19-5/20/30
Bed Volumes of Water Passed Between 1st & 2nd Regeneration		82,203	83,315	23,021
Bed Volumes of Steam Used		20 ½	22	18 ½
Loading - Carryover (g)*		0	58.1	10.9
Organics in Water (g)**		111.2	113.5	36.8
Superloading (g)***		-	28.9	-
Total Loading (g)		111.2	200.5	47.7
Organics Removed - Aqueous Phase		41.0	36.2	20.1
Estimated Volume-Organic Phase (ml)		52.5	80	6
Mass of Organic Phase (g)		78.8	120	9
Total Removed (g)		119.8	156.2	29.1
Organics Remaining (g)		0	44.3	18.6
Percentage Regeneration****		108%	78%	61%

* Organics remaining in resin after previous regeneration

** Organics removed from water during run prior to regeneration

*** Organics placed in resin due to superloading procedure

**** Percentage Regeneration = $\left(\frac{\text{Total Removal}}{\text{Total Loading}} \times 100\right)$

A problem of resin technology which has yet to be suitably addressed is the disposal of the condensate. The large amount of condensate collected, usually 20-30 bed volumes, makes disposal expensive. In an effort to deal with this, it was suggested to "superload" by introducing the condensate from one regeneration cycle into the column next ready to undergo regenetation. This step should further concentrate the organics, yielding a larger organic phase. Hence, the condensate from the steam-stripping at the end of column V's third run was passed through Column IV before that regeneration was attempted.

Figures 22 through 25 show that the second run of Column IV started off badly. Effluent concentrations of all contaminants were extremely high. 1,1,1-trichloroethane soon came down to levels expected in the resin effluent. Thereafter, lower concentrations occurred than in the first run. But the other contaminants remained quite high, although they did drop below the influent levels by day 50. There were considerable irregularities in the effluent charts. It is probable that with more frequent sampling the graphs would be even more erratic. Apparently, a plug of contaminants remained in the resin after regeneration which masked the normal performance. Of particular interest is that for cis-1,2-dichloroethylene, when the effluent concentration decreased to a similar level after 50 days, it follows the pattern set in the first run. The trichloroethylene line came down to the levels in run one, but only for a week. It then almost parallels the first run graph but at about 15 ug/l higher concentration. The tetrachloroethylene never did come down to levels shown in run one. It is significant, therefore, that after the second regeneration, which was a normal one, tetrachloroethylene, as well as the other contaminants were at levels which would be expected of regenerated resin.

Columns IV and V were again ready for regeneration simultaneously. After the second run, Column IV received a normal regeneration, while Column V was "superloaded" with Column IV condensate before steam-stripping. Even with superloading, the regeneration of Column V appears to have been successful (Figures 26 to 29). It was on a sample of condensate from this regeneration that an organic layer sample was completely analyzed, yielding a total concentration of 1.49 g/ml. There was not sufficient time in the program to be able to follow the path of the fifth run, but effluent concentrations of all contaminants were less than 5 ug/l after 15 days.

As observed in Figures 18 through 24, Column III, operating with downward flow, showed greater performance times than Columns IV and V.

The cis-1,2-dichloroethylene follows the pattern shown in Column V: initially second run concentrations are lower. But after a couple of months it crosses the first run effluent line. Again, this probably is due to the higher concentrations of cis-1,2-dichloroethylene in the influent. For the other compounds, the second run seems as good as or better than the first run.

ACTIVATED CARBON

Column I containing ICI activated carbon was the first to break through. Nineteen bed volumes of steam were passed through the column over a 24-hour period, in an attempt to regenerate the carbon. There was no phase separation in the condensate. As far as could be seen, all organics were dissolved in the water. This should result in improved accuracy in the percentage regeneration which is shown on Table 8. The final three samples of condensate showed less than 10 mg/l of organics. Yet, despite this, the percentage regeneration calculated was only slightly above 30%. That this accurately reflected what had happened can be seen in Figures 30 through 33 which show the performance of the carbon. For cis-dichloroethylene, 1,1,1-trichloroethane and trichloroethylene, breakthrough occurred in less than half the time for the second cycle. However, tetrachloroethylene, which had shown no appreciable breakthrough during the first cycle, did not show much difference between the first two cycles.

Because of the early breakthrough of the carbon in column I there was a second regeneration and a complete third cycle. The second try at steam-stripping removed 40% of the organics which the carbon had adsorbed since the first regeneration. However, because there was considerable carry over of contaminants on the carbon from the first cycle, the actual percentage regeneration was lower, 24%. These data also are listed in Table 8. As in the second cycle, the breakthroughs of cis-dichloroethylene, 1,1,1-trichloroethane and trichloroethylene occurred sooner than in the previous cycle. But in the third cycle, a noticeable increase in tetrachloroethylene occurred, indicating that despite the partial removal of organics during the regenerations, the accumulation of this compound on the carbon was approaching saturation.

Activated carbon Column II containing Calgon carbon had a slower start than Column I. Initially, the flow of water through it was restricted. It is natural, therefore, that this column lasted weeks longer before requiring regeneration. Yet, as Table 8 indicates, Column II passed about a third more bed volumes of water than did Column I, which may be due to the

TABLE 8

SUMMARY OF REGENERATION - ACTIVATED CARBON COLUMNS

	Column I	Column II
Composition	ICI Activated Carbon (Lignite)	Calgon Activated Carbon (coal)
Carbon Bed Volume (liters)	10	10
Direction of Water Flow	Down	Down
Direction of Steam	Up	Up
First Regeneration		
Dates	8/25-8/27/80	10/1-10/3/80
Bed Volumes of Water Passed until Regeneration	29,850	40,280
Bed Volumes of Steam Used	19	46
Loading - Carryover (g)*	-	-
Organics in Water (g)**	58.6	81.5
Total Loading (g)	58.6	81.5
Organics Removed - Aqueous Phase (g)	17.9	29.1
Estimated Volume-Organic Phase (ml)	0	0
Mass of Organic Phase (g)	0	0
Total Removed (g)	17.9	29.1
Organics Remaining (g)	40.7	52.4
Percentage Regeneration***	31%	36%
Second Regeneration		
Dates	11/18-11/19/80	
Bed Volumes of Water Passed Between 1st & 2nd Regeneration	25,960	
Bed Volumes of Steam Used	40	
Loading - Carryover (g)*	40.7	
Organics in Water (g)**	61.1	
Total Loading (g)	101.8	
Organics Removed - Aqueous Phase (g)	24.2	
Estimated Volume-Organic Phase (ml)	0	
Mass of Organic Phase (g)	0	
Total Removed (g)	24.2	
Organics Remaining (g)	77.6	
Percentage Regeneration***	24%	

* Organics remaining after previous regeneration

** Organics removed from water during run prior to regeneration

*** Percent Regeneration = $(\frac{\text{Total Removal}}{\text{Total Loading}} \times 100)$

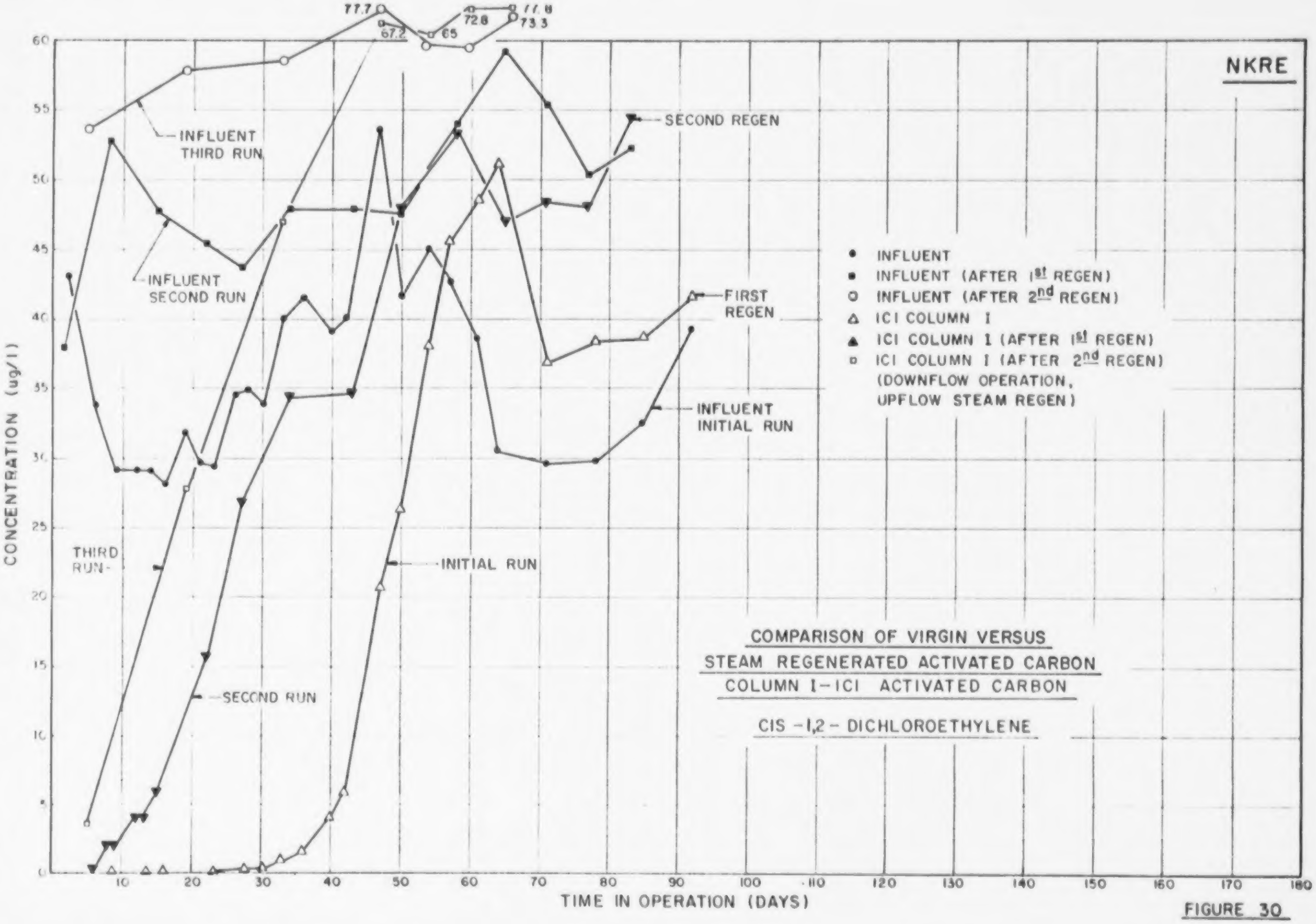

NKRE
COMPARISON OF VIRGIN VERSUS
STEAM REGENERATED ACTIVATED CARBON
COLUMN I – ICI ACTIVATED CARBON
CIS -1,2 - DICHLOROETHYLENE
● INFLUENT
■ INFLUENT (AFTER 1st REGEN)
○ INFLUENT (AFTER 2nd REGEN)
△ ICI COLUMN I
▲ ICI COLUMN I (AFTER 1st REGEN)
□ ICI COLUMN I (AFTER 2nd REGEN)
(DOWNFLOW OPERATION,
UPFLOW STEAM REGEN)
INFLUENT THIRD RUN
INFLUENT SECOND RUN
INFLUENT INITIAL RUN
SECOND REGEN
FIRST REGEN
THIRD RUN
SECOND RUN
INITIAL RUN
77.7
67.2
65
72.8
77.8
73.3
CONCENTRATION (ug/l)
60
55
50
45
40
35
30
25
20
15
10
5
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
TIME IN OPERATION (DAYS)

FIGURE 30

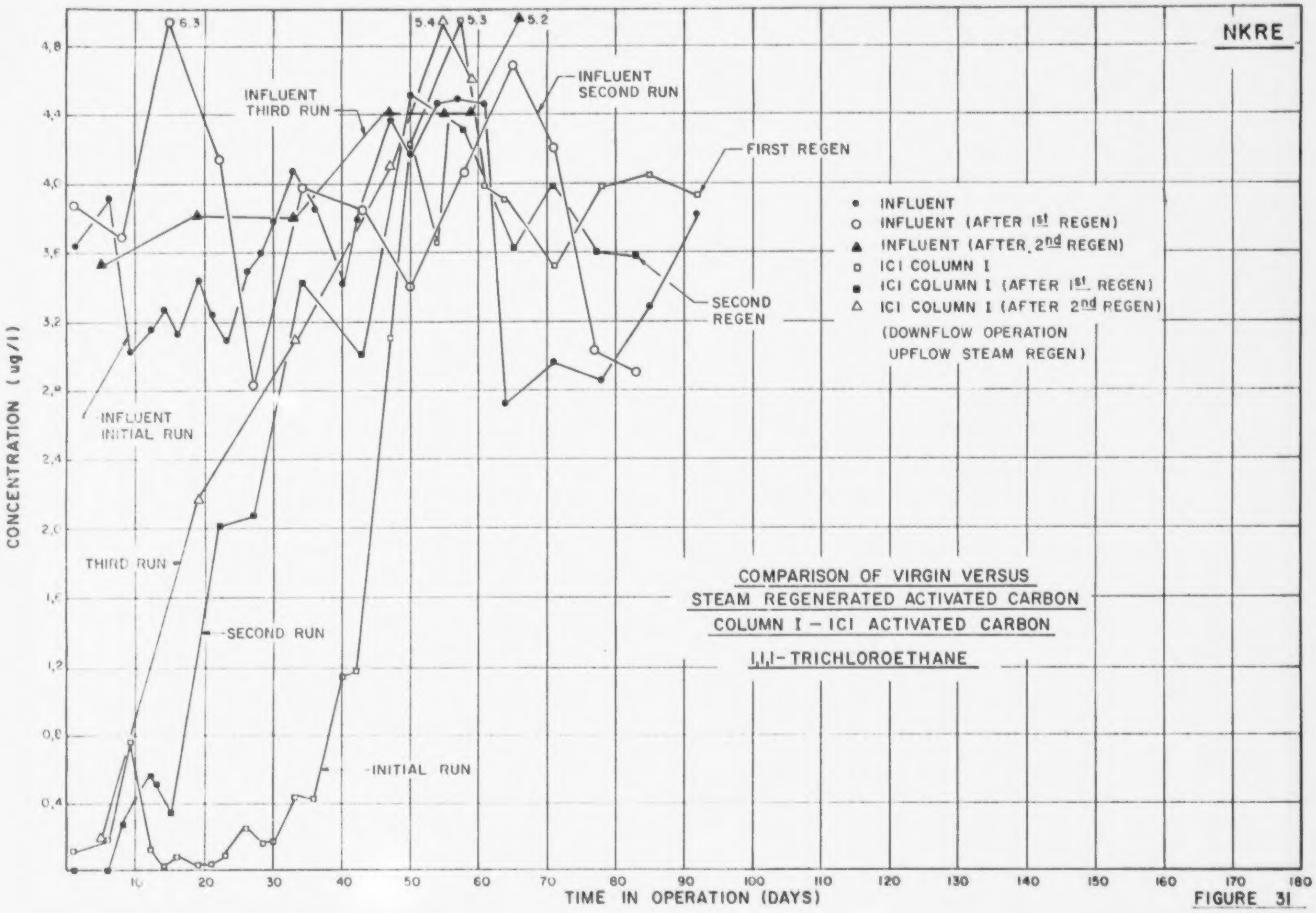
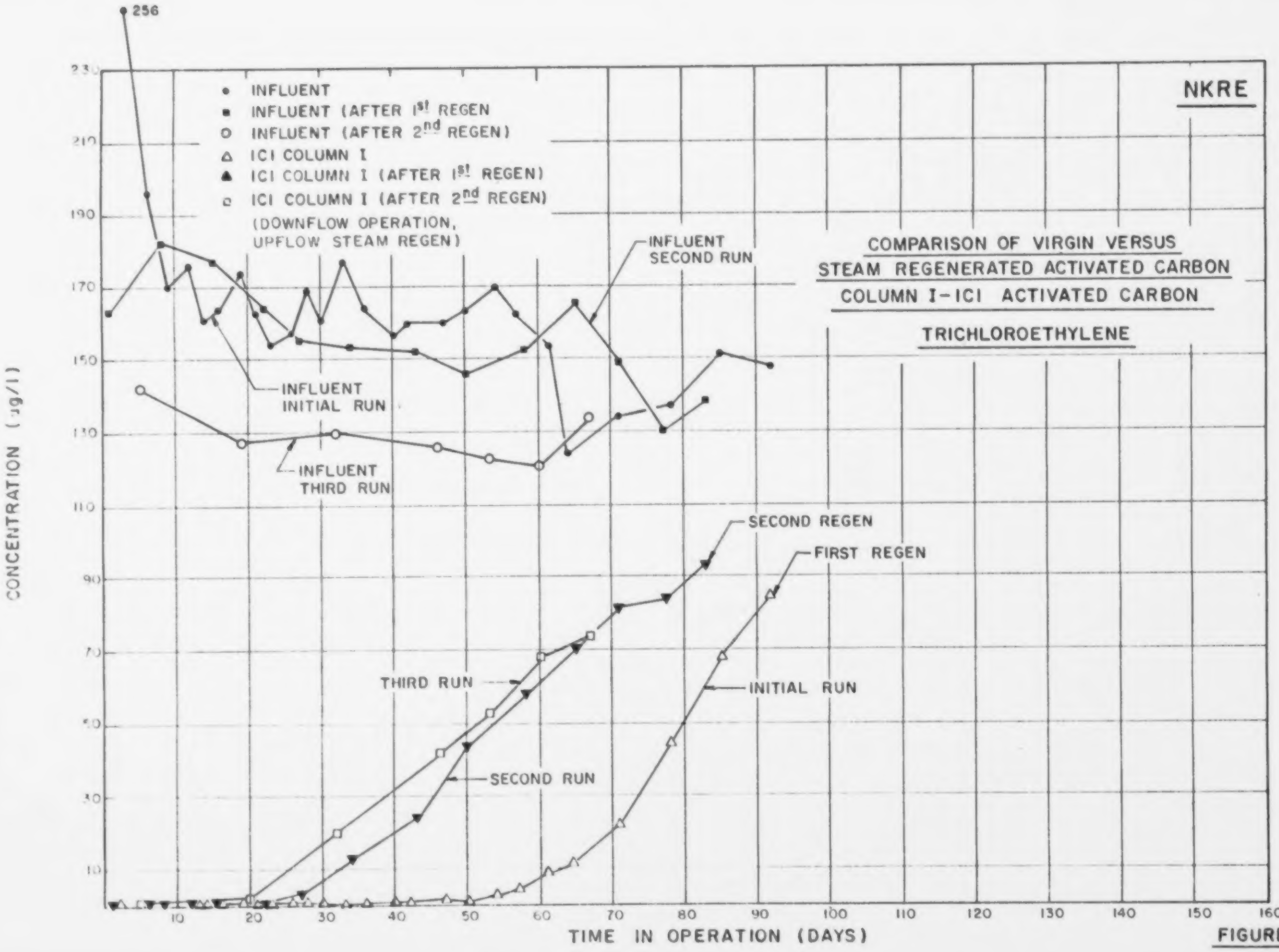

NKRE
CONCENTRATION (ug/l)
4,8
4,4
4,0
3,6
3,2
2,8
2,4
2,0
1,6
1,2
0,8
0,4
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
TIME IN OPERATION (DAYS)
6.3
5.4
5.3
5.2
INFLUENT THIRD RUN
INFLUENT SECOND RUN
FIRST REGEN
SECOND REGEN
INFLUENT INITIAL RUN
THIRD RUN
SECOND RUN
INITIAL RUN
● INFLUENT
○ INFLUENT (AFTER 1st REGEN)
▲ INFLUENT (AFTER 2nd REGEN)
□ ICI COLUMN I
■ ICI COLUMN I (AFTER 1st REGEN)
△ ICI COLUMN I (AFTER 2nd REGEN)
(DOWNFLOW OPERATION
UPFLOW STEAM REGEN)
COMPARISON OF VIRGIN VERSUS
STEAM REGENERATED ACTIVATED CARBON
COLUMN I - ICI ACTIVATED CARBON
1,1,1-TRICHLOROETHANE

FIGURE 31

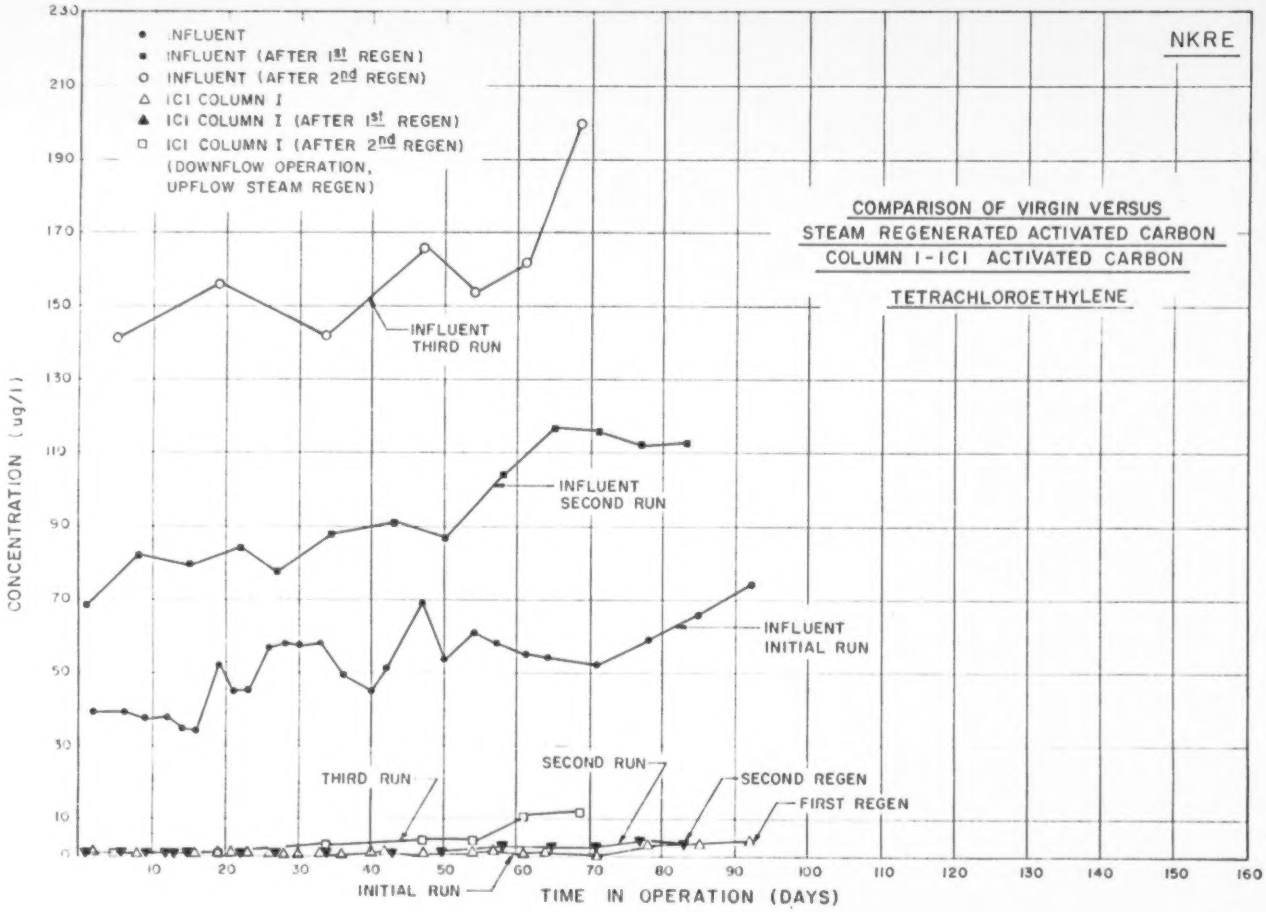


COMPARISON OF VIRGIN VERSUS STEAM REGENERATED ACTIVATED CARBON

COLUMN I-ICI ACTIVATED CARBON

TRICHLOROETHYLENE

FIGURE 32


COMPARISON OF VIRGIN VERSUS STEAM REGENERATED ACTIVATED CARBON COLUMN I-ICI ACTIVATED CARBON

TETRACHLOROETHYLENE

FIGURE 33

greater efficiency of operation of Column II being run at a lower application rate, and may reflect inherent differences in the types of activated carbon. As with Column I, the calculated 36 percentage regeneration for Column II is low and this low regeneration is reflected in the breakthrough curves presented on Figures 34 through 37. Here, too, no phase separation was observed in the condensate.

As expected in a poor regeneration, the breakthrough for the second run occurred much sooner than in the first run. However, by the time Column II was ready for a second regeneration, it had been decided that little additional data could be learned from additional regenerations. The column was allowed to continue running until the end of Phase II field tests. The result is that for cis-1,2-dichloroethylene, 1,1,1-trichloroethane and trichloroethylene, leakage reached, or exceeded the influent concentrations. The tetrachloroethylene effluent level never reached more than 10% of the influent levels; however, it was noticeably higher than for the first run after about 70 days of operation.

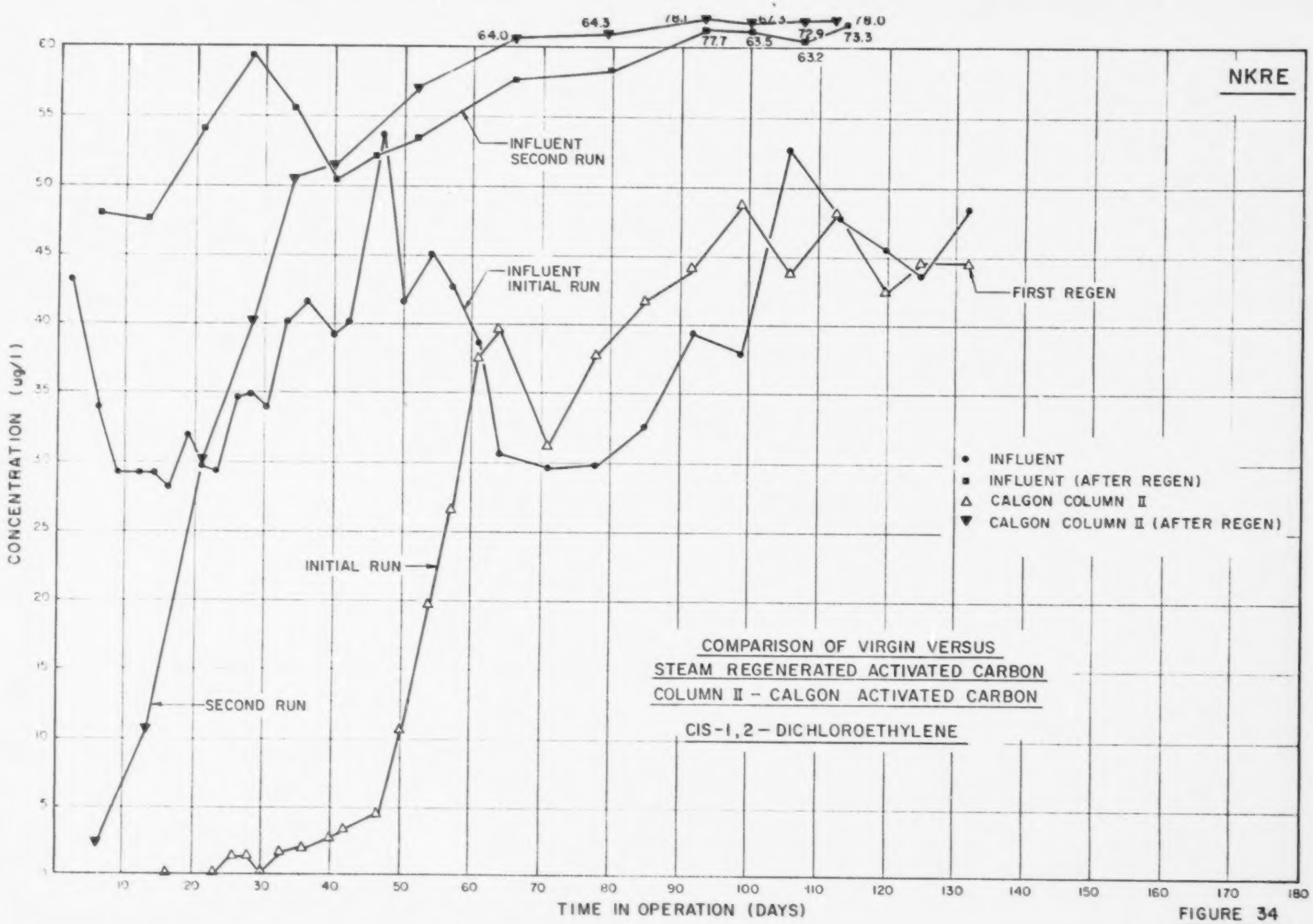
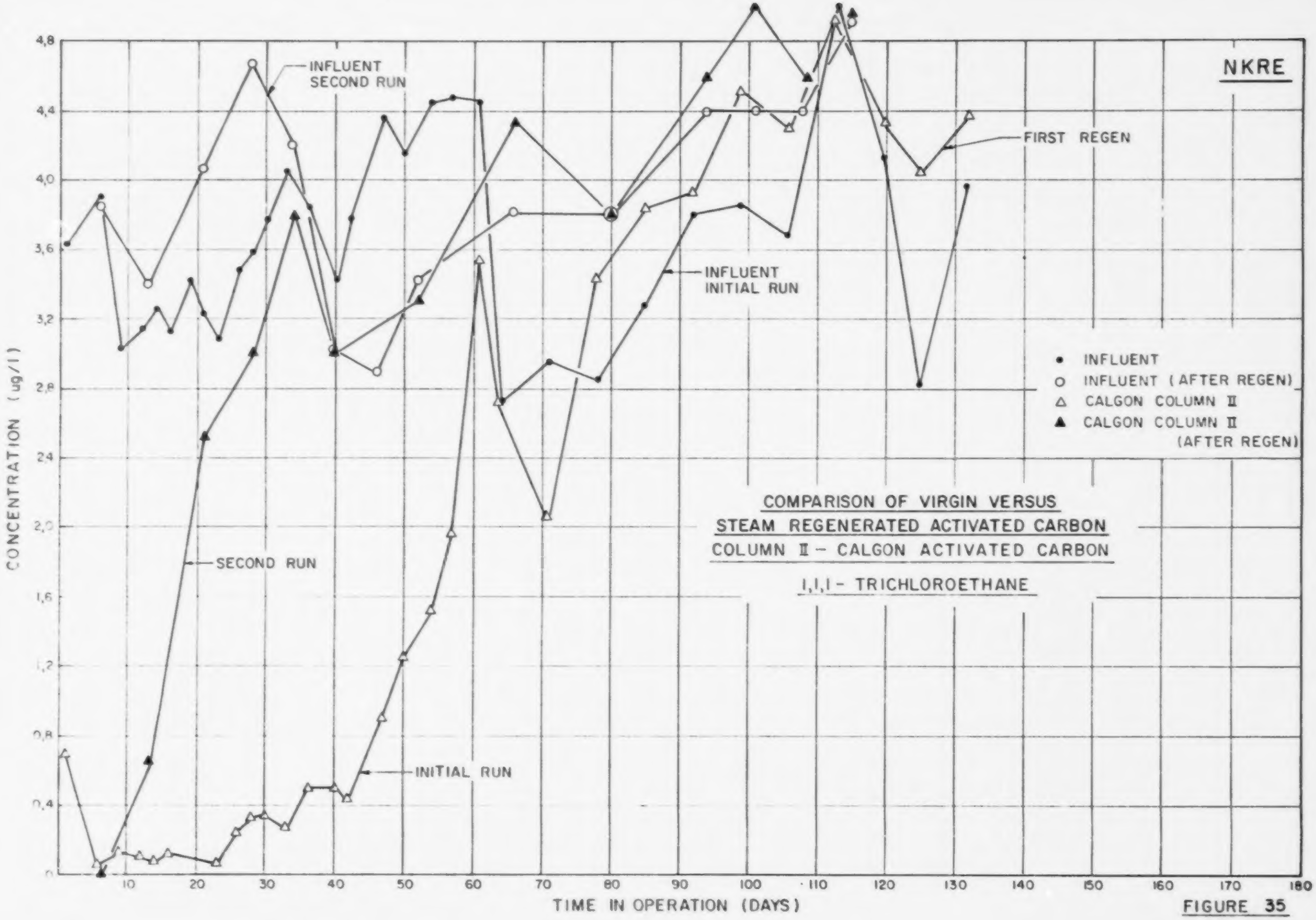

NKRE
COMPARISON OF VIRGIN VERSUS
STEAM REGENERATED ACTIVATED CARBON
COLUMN II - CALGON ACTIVATED CARBON
CIS-1,2-DICHLOROETHYLENE
● INFLUENT
■ INFLUENT (AFTER REGEN)
△ CALGON COLUMN II
▼ CALGON COLUMN II (AFTER REGEN)
INFLUENT SECOND RUN
INFLUENT INITIAL RUN
INITIAL RUN
SECOND RUN
FIRST REGEN
64.0
64.3
78.1
67.3
78.0
77.7
63.5
72.9
73.3
63.2
CONCENTRATION (ug/l)
60
55
50
45
40
35
30
25
20
15
10
5
1
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
TIME IN OPERATION (DAYS)

FIGURE 34



COMPARISON OF VIRGIN VERSUS
STEAM REGENERATED ACTIVATED CARBON
COLUMN II - CALGON ACTIVATED CARBON
1,1,1- TRICHLOROETHANE

FIGURE 35

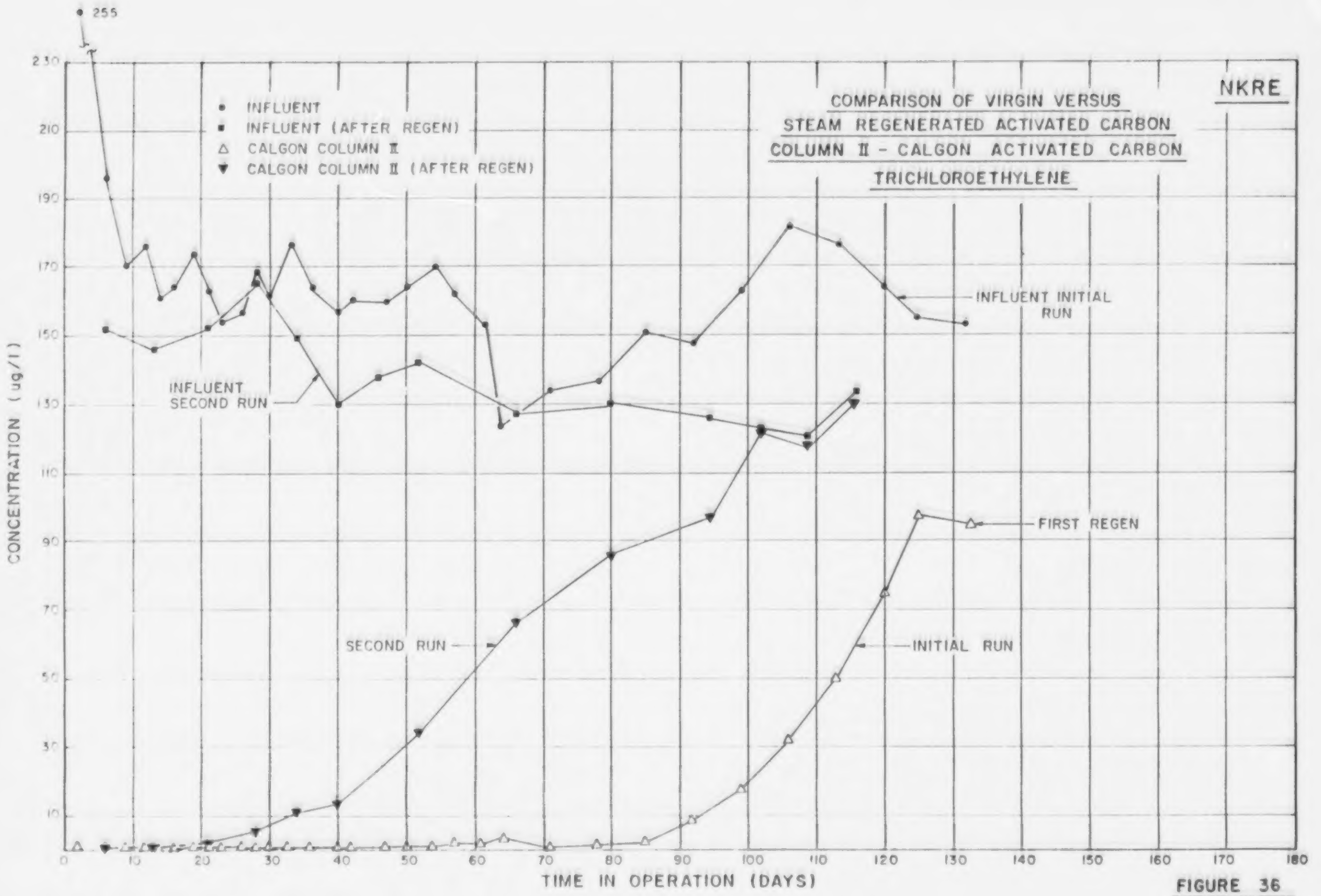

NKRE
COMPARISON OF VIRGIN VERSUS
STEAM REGENERATED ACTIVATED CARBON
COLUMN II - CALGON ACTIVATED CARBON
TRICHLOROETHYLENE
● INFLUENT
■ INFLUENT (AFTER REGEN)
△ CALGON COLUMN II
▼ CALGON COLUMN II (AFTER REGEN)
255
INFLUENT INITIAL RUN
INFLUENT SECOND RUN
FIRST REGEN
SECOND RUN
INITIAL RUN
CONCENTRATION (ug/l)
230
210
190
170
150
130
110
90
70
50
30
10
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
TIME IN OPERATION (DAYS)

FIGURE 36

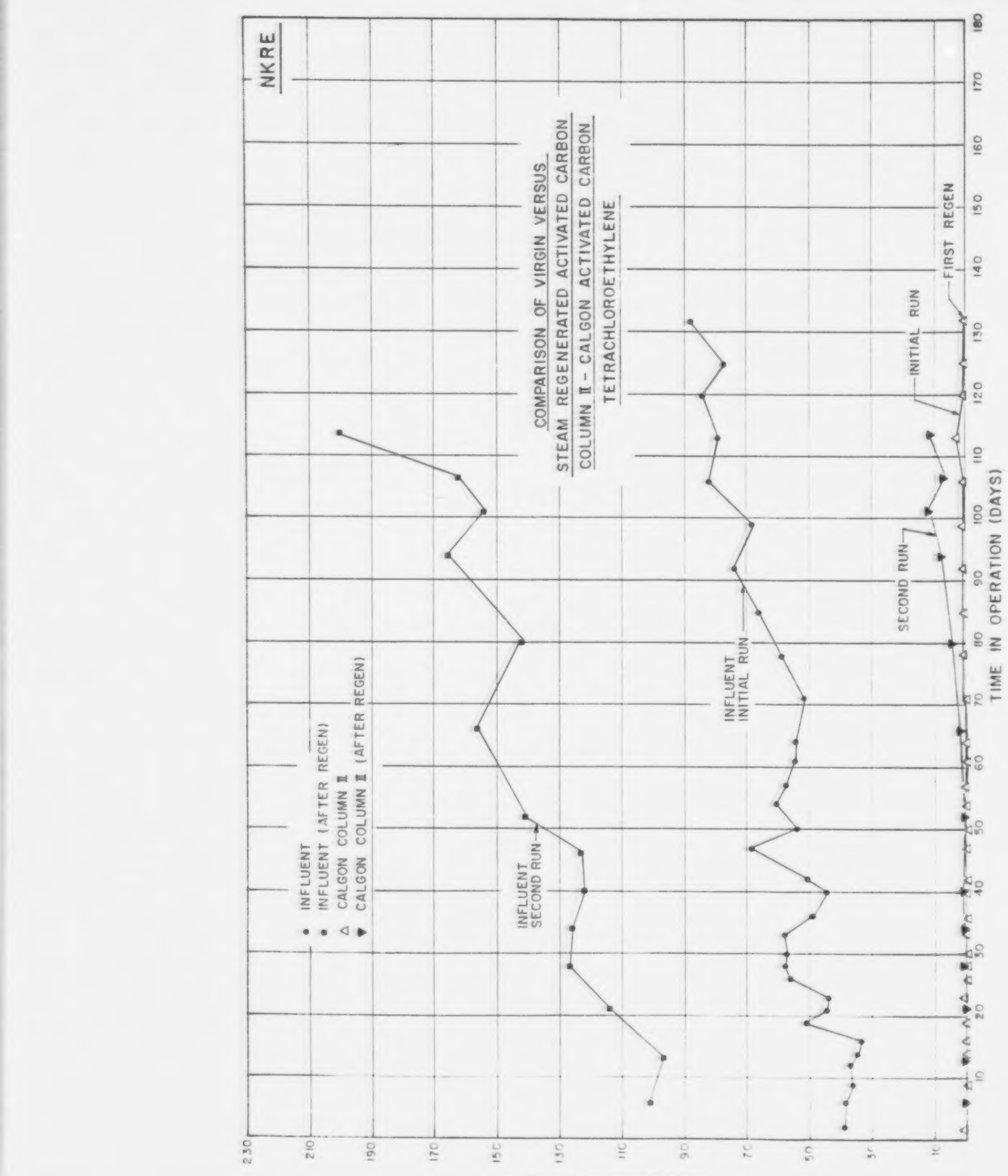

NKRE
COMPARISON OF VIRGIN VERSUS
STEAM REGENERATED ACTIVATED CARBON
COLUMN II - CALGON ACTIVATED CARBON
TETRACHLOROETHYLENE
● INFLUENT
■ INFLUENT (AFTER REGEN)
△ CALGON COLUMN II
▼ CALGON COLUMN II (AFTER REGEN)
INFLUENT SECOND RUN
INFLUENT INITIAL RUN
SECOND RUN
INITIAL RUN
FIRST REGEN
CONCENTRATION (ug/l)
230
210
190
170
150
130
110
90
70
50
30
10
TIME IN OPERATION (DAYS)
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180

FIGURE 37

SECTION 8

FULL SCALE INSTALLATIONS - COSTS

ADAPTABILITY OF SYSTEMS

A. Diffused Aeration System

As indicated in the Phase I report, this system can be designed and installed for a full-scale operation if the desired contaminant removal is not less than that achievable at the air to water ratios used in the Phase I and Phase II reports. It should be restated that the diffused aeration system should be capable of producing a water quality which would meet present New York State guidelines.

B. Packed Column Aeration System

The packed column aeration system produced an equivalent or better water quality than the diffused aeration system, so the same statements made for diffused aeration apply to packed column aeration.

C. Resin System

As indicated in the Phase I report, the resin system achieved a better water quality than any of the aeration systems evaluated. While the testing in this phase did define more of the required design parameters, such as flow application and direction of steam regeneration, additional data such as proper method of handling the steam condensate should be further explored prior to a full-scale installation. In any case, the steam condensate can be hauled to an approved chemical disposal site.

ESTIMATED COSTS FOR FULL-SCALE INSTALLATIONS

As in the Phase I report, flows of 1, 2 and 5 mgd (3785, 7575 and 18925 m^3/day) were utilized to obtain a range of costs for a full-scale installation. These flows were utilized in the costing of the diffused aeration system, packed column aeration system and resin system. All costs in the report were estimated by NKRE using the most recently available costing information in March 1981. All the estimated costs include required buildings for equipment and electricity but not laboratory, offices or facilities for workmen.

A. Diffused Aeration System

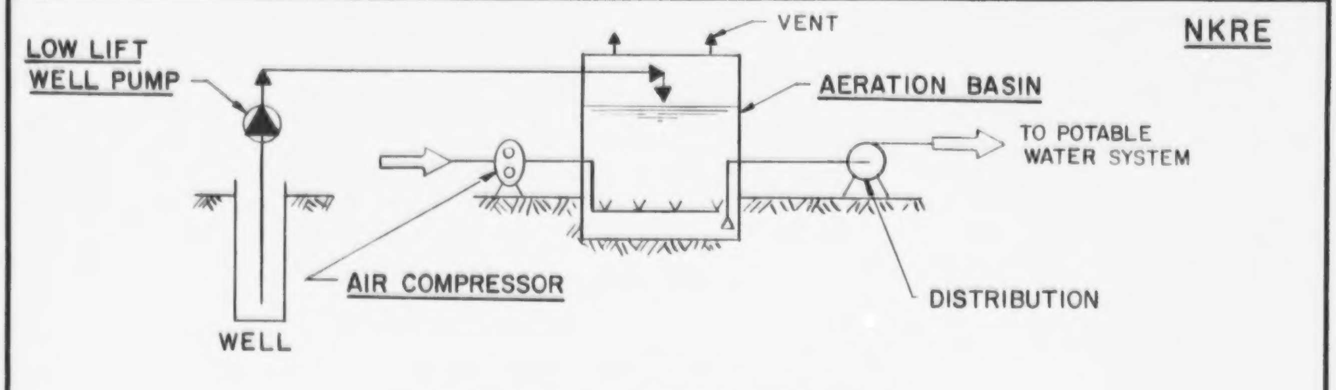
Utilizing the flows previously indicated and based on a 20:1 air to water ratio, the units necessary for the aeration system shown schematically on Figure 38 were sized and their cost estimated. This estimated cost includes the replacement of a high pressure well pump with a low lift well pump, storage-aeration tank for 25 minutes detention time, pumps to feed the distribution system after treatment and a control building to house the blowers, distribution pumps, electrical equipment and required instrumentation. The storage-aeration tank should provide sufficient capacity to guarantee a continuous water supply to the consumer in case of well pump failure. This 25 minute designed detention time will most likely result in improved effluent quality over that achieved by the 10 minute detention time utilized during the Phase II study. Based on the parameters and the system as indicated on Figure 38, the estimated capital costs for the flows indicated range from $228,200 to $470,700. The estimated annual operating costs, including amortization, maintenance, operations and electricity at a local cost of $0.09 per kWh, range from $122,000 to $341,500, or between $0.19 and $0.33 per 1000 gallons (3,785 liters) of treated water. This cost is relatively high, mainly due to the local cost of electricity. A summary of the estimated cost is presented on Table 9 and on Figures 39, 40 and 41.

B. Packed Column Aeration System

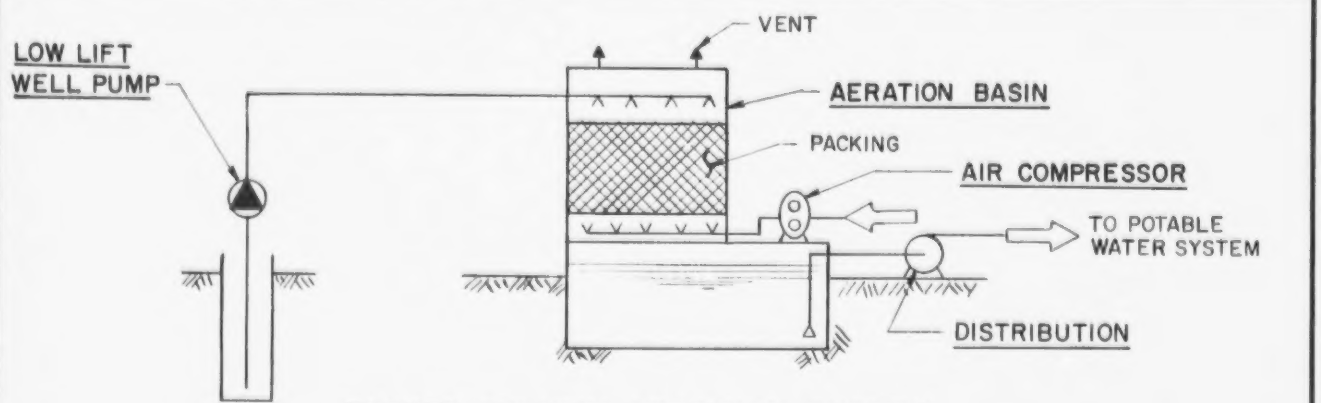
Utilizing the same parameters as previously indicated, and including all items necessary for the diffused aeration system, the cost estimated for the packed column aeration system shown on Figure 3 was prepared. The estimated cost, including required packing (based on Munters packing used during this testing), for the flows indicated range from $275,000 to $650,500. The estimated annual operating cost for the packed column aeration system, including amortization, maintenance, operations and electricity at a local cost of $0.09 per kWh, range from $117,000 to $308,600, or between $0.17 to $0.32 per 1000 gallons (3,785 liters) of treated water. Again this cost is relatively high mainly due to the local cost of electricity. A summary of the estimated cost is presented on Table 10 and on Figures 42, 43 and 44.

C. Resin System

In Phase I the estimated costs were based on costs provided by the manufacturer, Rohm and Haas. The estimated costs for Phase II were developed by NKRE utilizing the data obtained


NKRE
LOW LIFT WELL PUMP
VENT
AERATION BASIN
TO POTABLE WATER SYSTEM
AIR COMPRESSOR
DISTRIBUTION
WELL

DIFFUSED AERATION SYSTEM


LOW LIFT WELL PUMP
VENT
AERATION BASIN
PACKING
AIR COMPRESSOR
TO POTABLE WATER SYSTEM
DISTRIBUTION
WELL

PACKED COLUMN AERATION SYSTEM

FIGURE 38

TABLE 9

COST ESTIMATE - DIFFUSED AERATION SYSTEM
(Based on 1981 Dollars)

	1 MGD (3785 m^3/d)	2 MGD (7570 m^3/d)	5 MGD (18925 m^3/d)
A. CAPITAL COST			
1. Excavation	700	800	200
2. Concrete	37,000	46,000	68,000
3. Low Lift Well Pump	25,000	31,000	44,000
4. Distribution Pump	13,000	13,500	34,000
5. Air Blower	41,500	56,000	126,000
6. Piping, Valves, etc.	19,000	25,000	57,000
7. Superstructure	70,000	70,000	87,500
8. Heating and Ventilating	6,000	6,000	8,000
9. Elec. & Instr.	16,000	21,000	48,000
	228,200	269,300	472,000
B. ANNUAL OPERATING COST			
1. Electricity			
0.03/kWh	20,000	40,000	80,000
0.06/kWh	40,000	80,000	160,000
0.09/kWh	60,000	120,000	240,000
0.12/kWh	80,000	160,000	320,000
2. Maintenance 3% of Equipment Cost	4,000	4,500	9,500
3. Operators	20,000	20,000	20,000
4. Quality Control	9,000	9,000	9,000
5. Amortization			
Construction (@ 8% for 20 yrs; CFR 0.10185)	11,000	12,000	16,000
Mechanical (@ 8% for 10 yrs; CFR 0.14903)	18,000	21,000	47,000
Total Estimated Annual Cost			
0.03/kWh	82,000	106,500	181,500
0.06/kWh	102,000	146,500	261,500
0.09/kWh	122,000	186,500	341,500
0.12/kWh	142,000	226,500	421,500
Cost per 1000 gal. Treated			
0.03/kWh	0.225	0.146	0.099
0.06/kWh	0.279	0.201	0.143
0.09/kWh	0.334	0.255	0.187
0.12/kWh	0.389	0.310	0.231

NKRE

DIFFUSED AERATION SYSTEM
CAPITAL COST

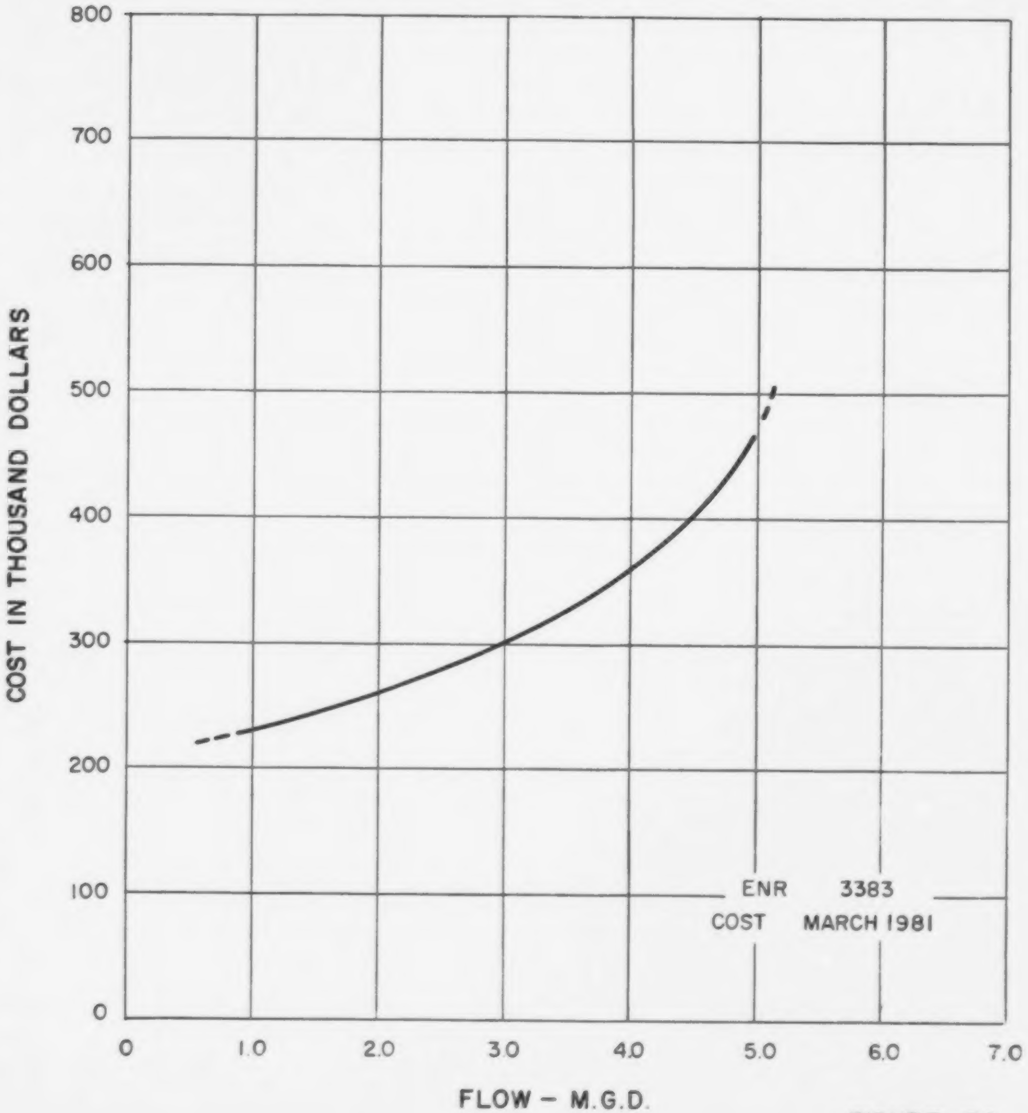


FIGURE 39

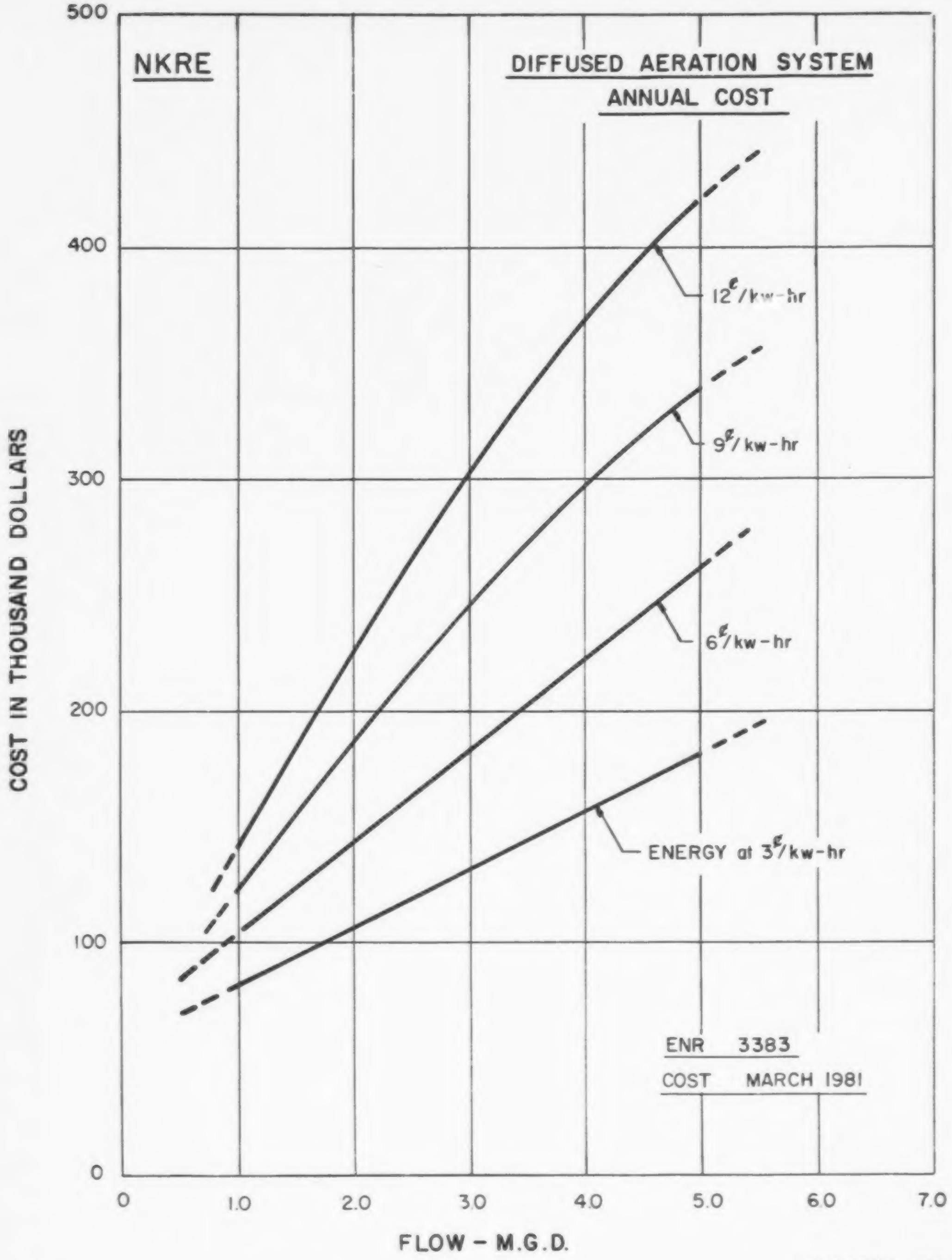

NKRE
DIFFUSED AERATION SYSTEM
ANNUAL COST
12¢/kw-hr
9¢/kw-hr
6¢/kw-hr
ENERGY at 3¢/kw-hr
ENR 3383
COST MARCH 1981
COST IN THOUSAND DOLLARS
500
400
300
200
100
0
0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
FLOW - M.G.D.

FIGURE 40

NKRE

DIFFUSED AERATION SYSTEM ANNUAL COST PER THOUSAND GALLONS TREATED

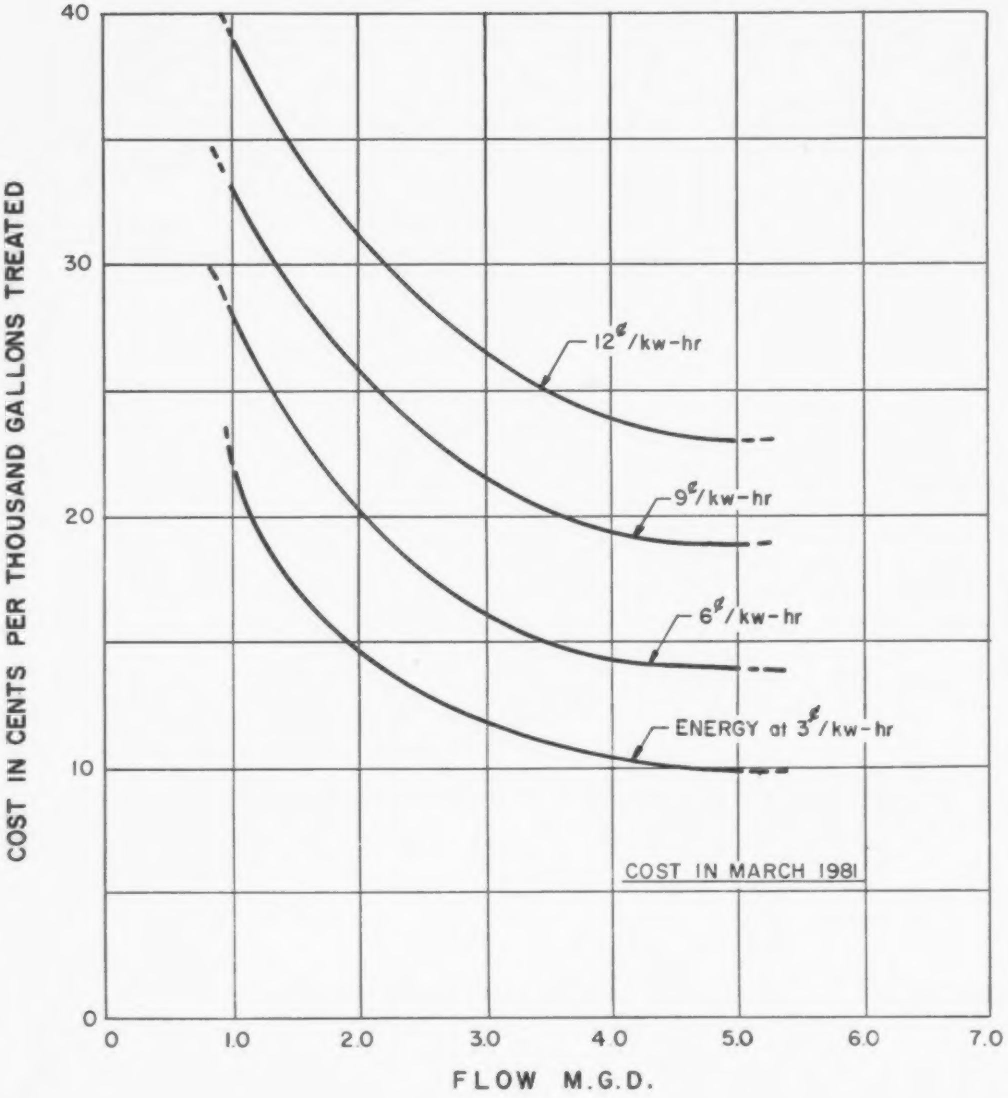


FIGURE 41

TABLE 10

COST ESTIMATE - PACKED COLUMN AERATION SYSTEM
(Based on 1981 Dollars)

	1 MGD (3785 m^3/d)	2 MGD (7570 m^3/d)	5 MGD (18925 m^3/d)
A. CAPITAL COST			
1. Excavation	1,000	1,500	3,000
2. Concrete	43,000	72,000	93,000
3. Low Lift Well Pump	25,000	31,000	44,000
4. Distribution Pump	13,000	13,500	34,000
5. Air Blower	40,000	54,000	107,000
6. Packing	42,000	69,000	183,000
7. Piping, Valves, etc.	19,000	24,000	49,000
8. Superstructure	70,000	70,000	87,500
9. H & V	6,000	6,000	8,000
10. Elec. & Instr.	16,000	20,000	42,000
	275,000	361,000	650,500
B. ANNUAL OPERATING COST			
1. Electricity			
0.03/kWh	15,500	29,000	59,000
0.06/kWh	31,000	59,000	117,500
0.09/kWh	47,000	88,000	176,000
0.12/kWh	62,500	117,500	235,000
2. Maintenance 3% of Equipment Cost	5,000	7,000	15,000
3. Operators	20,000	20,000	20,000
4. Quality Control	9,000	9,000	9,000
5. Amortization			
Construction (@ 8% for 20 yrs; CFR 0.10185)	12,000	15,000	19,000
Mechanical (@ 8% for 10 yrs; CFR 0.14903)	24,000	32,000	69,600
Total Estimated Annual Cost			
0.03/kWh	85,500	112,000	191,600
0.06/kWh	101,000	142,000	250,100
0.09/kWh	117,000	171,000	308,600
0.12/kWh	132,500	200,500	367,600
Cost per 1000 gal. Treated			
0.03/kWh	0.234	0.153	0.105
0.06/kWh	0.277	0.195	0.137
0.09/kWh	0.321	0.234	0.169
0.12/kWh	0.363	0.275	0.201

PACKED COLUMN AERATION SYSTEM
CAPITAL COST

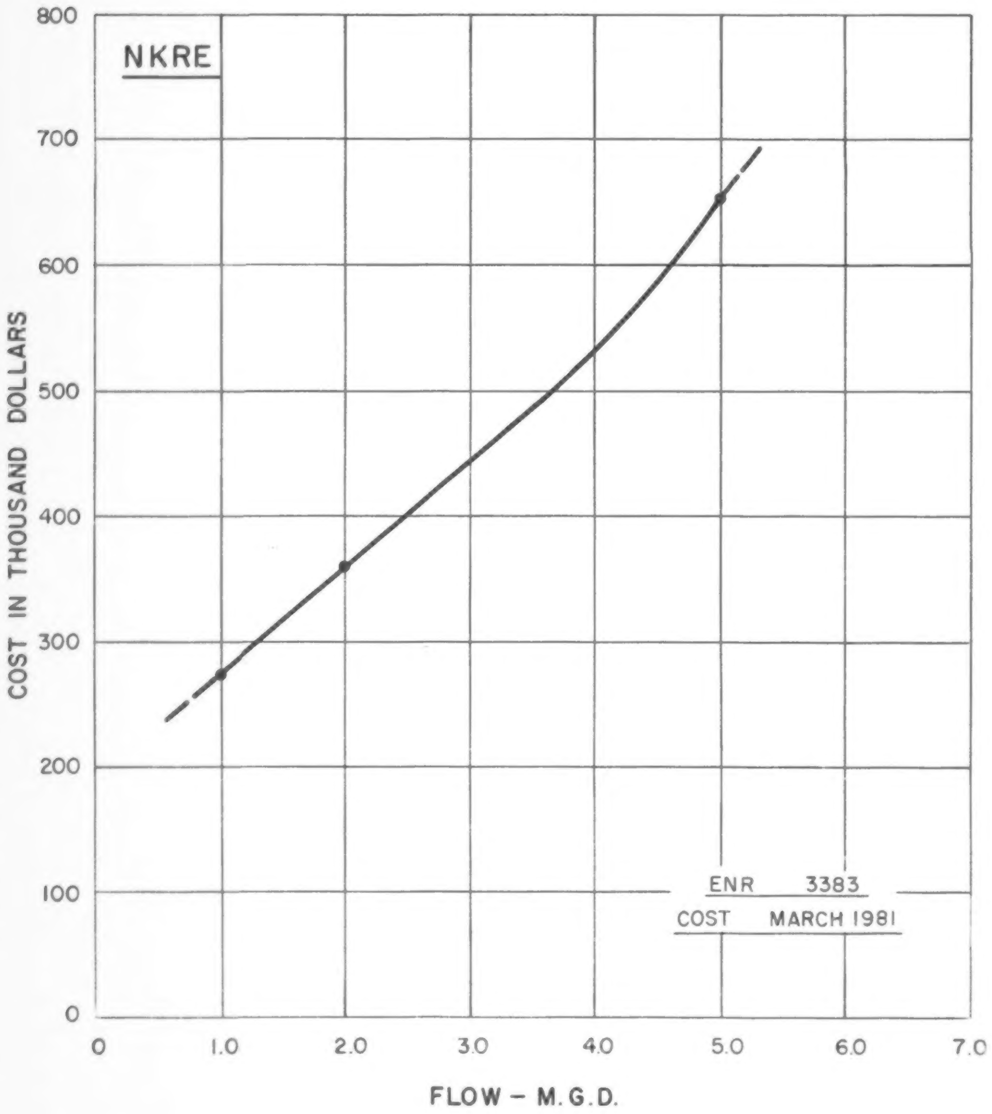


FIGURE 42

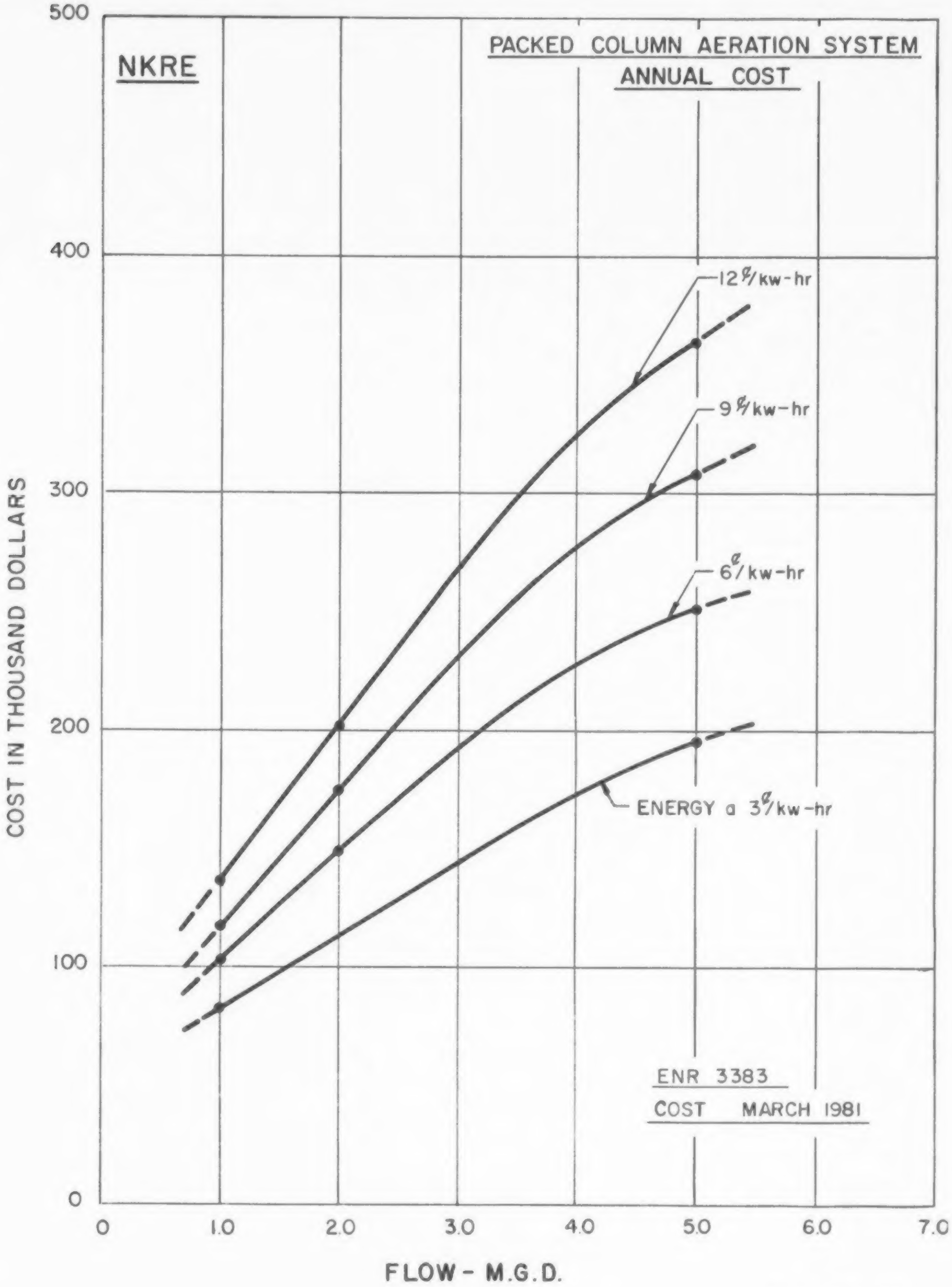

NKRE
PACKED COLUMN AERATION SYSTEM
ANNUAL COST
12¢/kw-hr
9¢/kw-hr
6¢/kw-hr
ENERGY a 3¢/kw-hr
ENR 3383
COST MARCH 1981
COST IN THOUSAND DOLLARS
500
400
300
200
100
0
0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
FLOW - M.G.D.

FIGURE 43

NKRE

PACKED COLUMN AERATION SYSTEM
COST PER THOUSAND
GALLONS TREATED

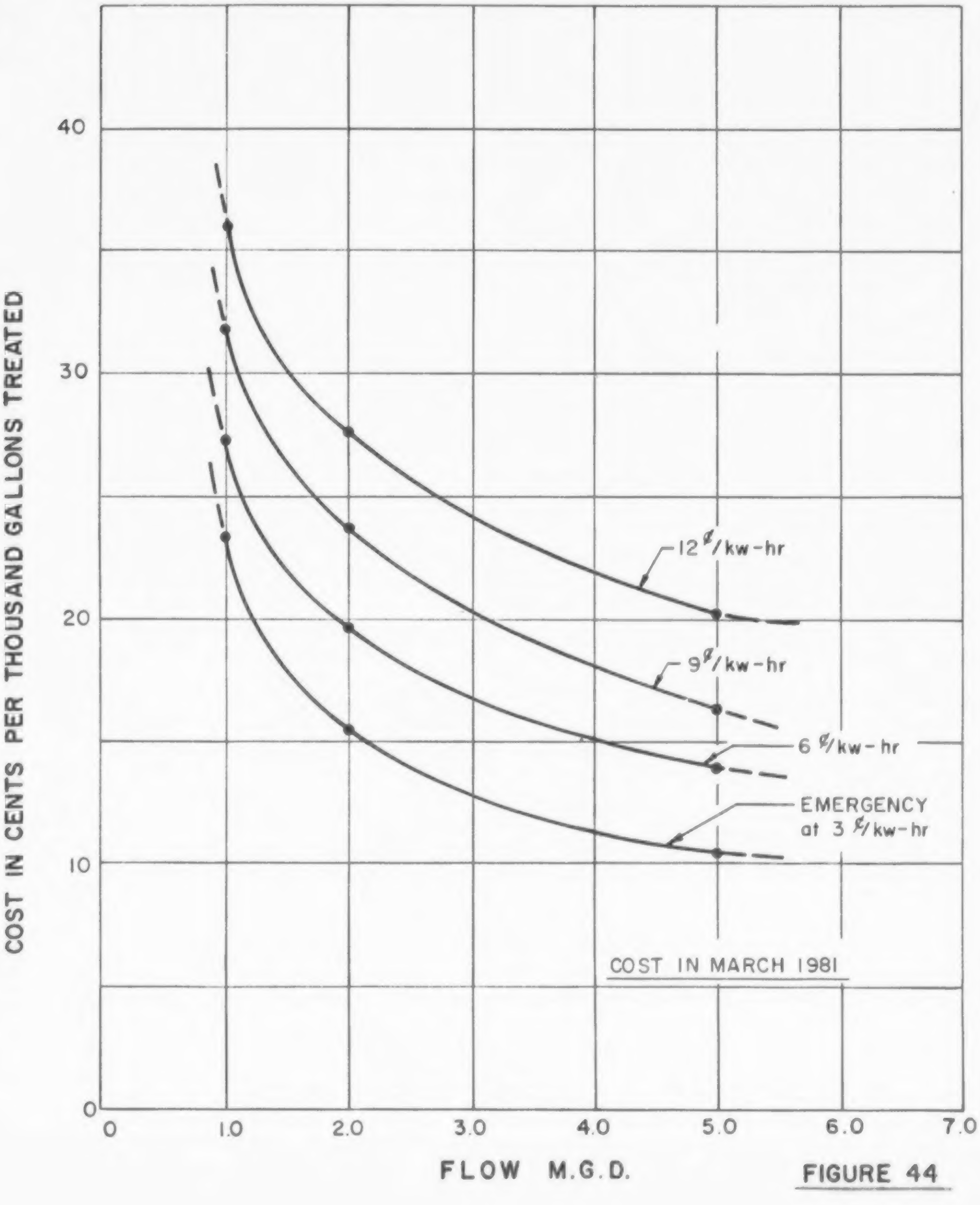
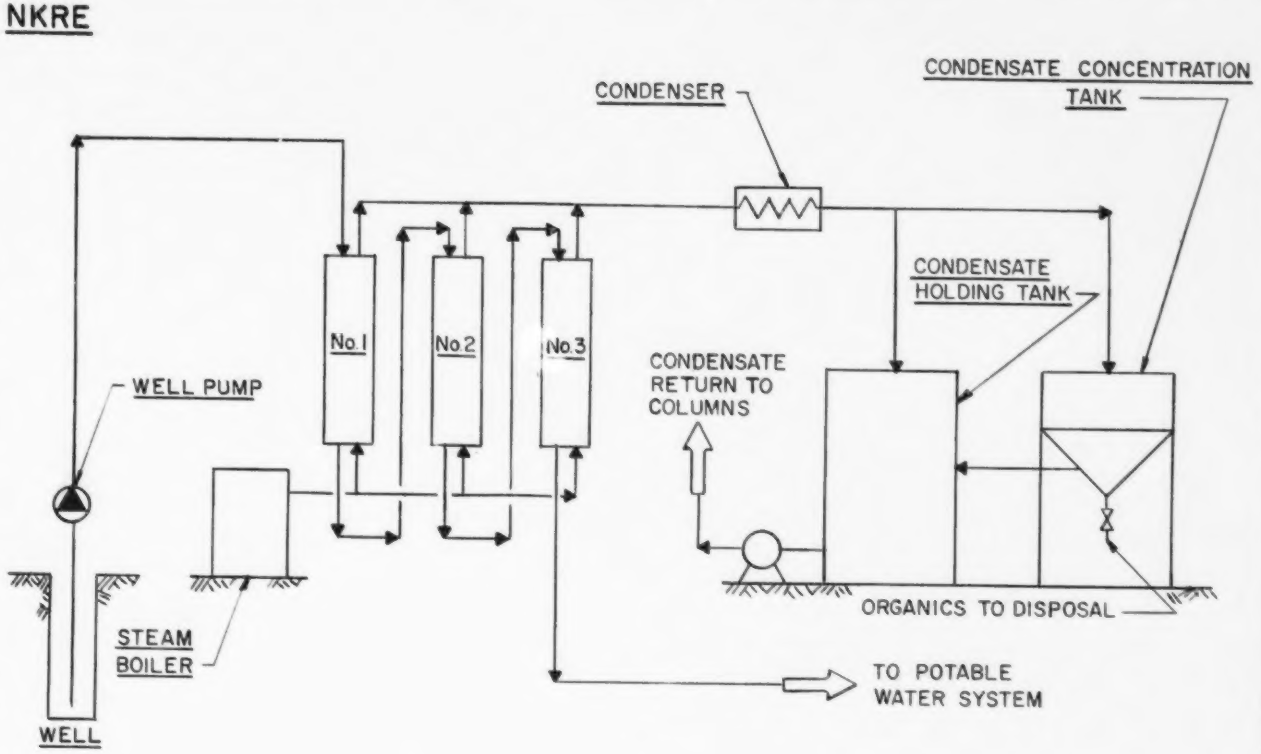


FIGURE 44

during both phases of the program. This estimated cost includes all units shown schematically on Figure 45 necessary to treat the water by resin, to steam regenerate the resin, to collect and treat the steam condensate and a building to house the entire system. The estimated capital cost, based on 4 gpm/ft^3 (0.42 lpm/m^3) of adsorbent, for the flows indicated range from $308,250 to $953,400. The resin system has an estimated annual operating cost, including amortization, maintenance, operation, fuel for steam production, electricity at $0.09 per kWh, and other requirements such as solvent for hydration, ranging from $0.12 to $0.22 per 1000 gallons (3785 liters) treated. These cost estimates do not include any well or distribution pumps since it was assumed that any existing high pressure well pump would be sufficient to overcome the headloss through the resin and feed the distribution system. The operating cost includes regeneration of each column three (3) times per year. A summary of these estimated costs is presented on Table 11 and on Figures 46, 47 and 48.

D. Summary of Estimated Costs

The capital cost for the three possible treatment methods, diffused aeration, packed column aeration and resin adsorption, are compared on Figure 49. The data presented on Figure 49 indicates that the resin system has the highest capital cost, the diffused aeration system has the lowest capital cost and the packed column aeration system is between the two. It should be noted that 40-65% of the capital cost for the resin system is due to required piping and valves, particularly those associated with steam regeneration. Figure 50 compares the operating cost for each system considering electrical cost at $0.09/kWh, and shows that the resin system has the lowest operating cost with the diffused aeration system having the highest and again the packed column aeration system is in between the other two. The higher costs for the aeration systems are due to the electrical power required to provide the required air. These costs could be reduced if environmentally acceptable alternate methods of air introduction can be demonstrated and utilized. The cost of disposing of condensate from the steam regeneration of resin is only an assumption. The actual method and cost of disposal must be further developed.


NKRE
CONDENSER
CONDENSATE CONCENTRATION TANK
CONDENSATE HOLDING TANK
No.1
No.2
No.3
CONDENSATE RETURN TO COLUMNS
WELL PUMP
STEAM BOILER
WELL
ORGANICS TO DISPOSAL
TO POTABLE WATER SYSTEM

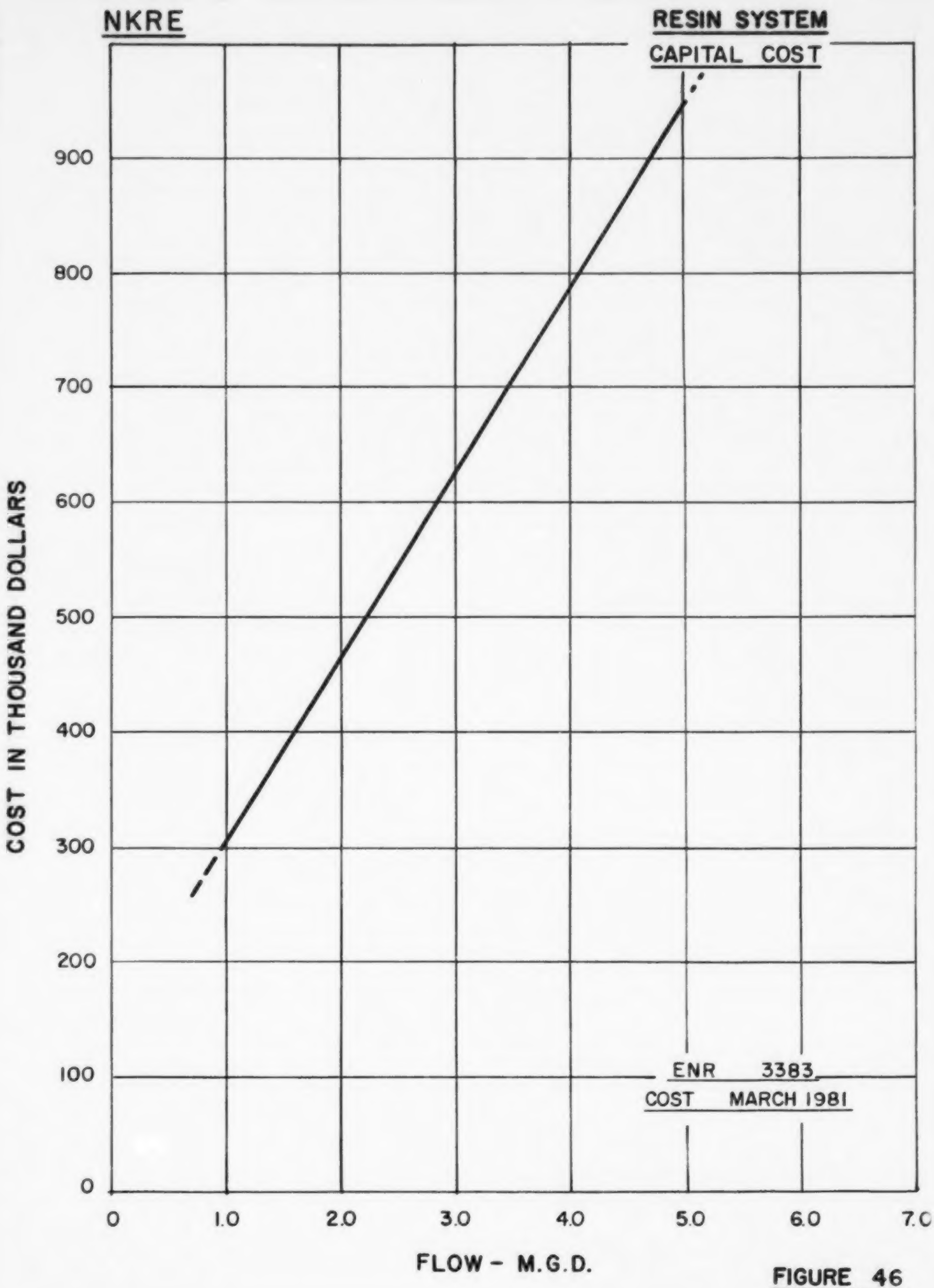
RESIN SYSTEM

FIGURE 45

TABLE 11

COST ESTIMATE - RESIN SYSTEM
(Based on 1981 Dollars)

	1 MGD (3785 m^3/d)	2 MGD (7570 m^3/d)	5 MGD (18925 m^3/d)
A. CAPITAL COST			
1. Excavation	250	300	400
2. Concrete	22,000	28,000	39,000
3. Vessels (insulated)	22,000	44,000	110,000
4. Well Pump	Not included	Not included	Not included
5. Resin (including installation & initial solvent for hydrating resin)	68,000	133,000	326,000
6. Distribution Pump	Not included	Not included	Not included
7. Steam Generator	13,000	13,000	13,000
8. Condenser	1,000	1,000	1,000
9. Condensate Holding Tank	24,000	24,000	24,000
10. Condensate Concentration Tank	14,000	14,000	14,000
11. Condensate Transfer Pump	4,000	4,000	4,000
12. Oil Storage Tank (1000 gal.)	2,000	2,000	2,000
13. Piping, Valves, etc.	52,000	114,000	286,000
14. H & V	6,000	7,500	9,000
15. Superstructure	75,000	87,500	119,000
16. Elec. & Instrumentation	5,000	5,000	6,000
	308,250	477,300	953,400
B. ANNUAL OPERATING COST			
1. Adsorbent Makeup ($7/lb.) (Estimated life - 8 yrs)	8,000	16,000	40,000
2. Solvent	500	1,000	2,500
3. Electricity			
0.03/kWh	500	1,000	2,500
0.06/kWh	1,000	2,000	5,000
0.09/kWh	1,500	3,000	7,500
0.12/kWh	2,000	4,000	10,000
4. Fuel (No. 2 oil) (For Steam Generator)	2,000	4,000	10,000
5. Disposal of Organics	200	400	1,000
6. Maintenance (3% of Equipment Cost)	3,500	5,000	10,500
7. Operators	20,000	20,000	20,000
8. Quality Control	9,000	9,000	9,000
9. Amortization			
Construction (8% for 20 yrs; CFR 0.10185)	19,000	23,000	60,000
Mechanical (8% for 10 yrs; CFR 0.14903)	18,000	27,000	54,000
Total Annual Cost			
0.03/kWh	80,700	106,400	209,500
0.06/kWh	81,200	107,400	212,000
0.09/kWh	81,700	108,400	214,500
0.12/kWh	82,200	109,400	217,000
Cost per 1000 gal. Treated Water			
0.03/kWh	0.220	0.146	0.115
0.06/kWh	0.222	0.147	0.116
0.09/kWh	0.224	0.148	0.118
0.12/kWh	0.225	0.150	0.119


NKRE

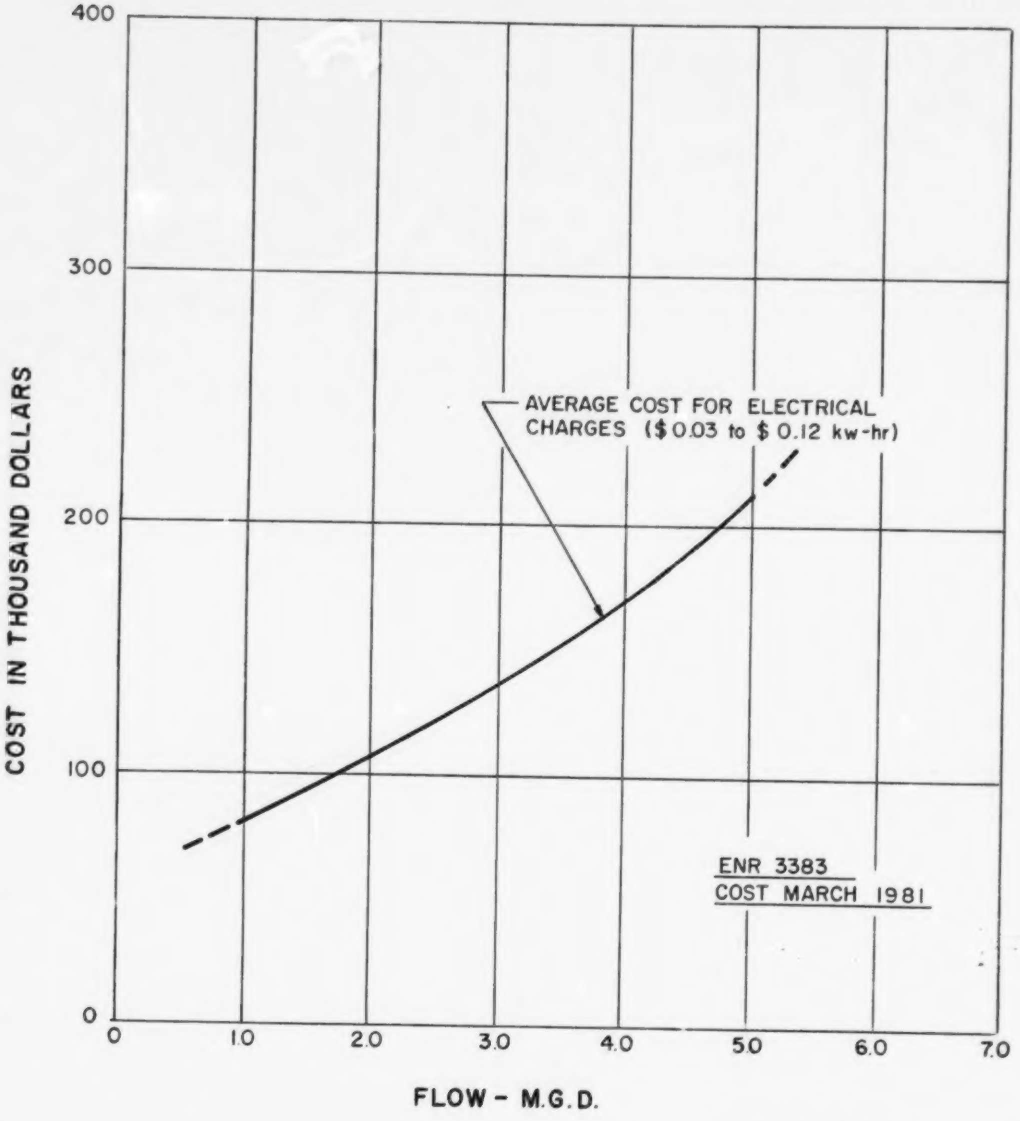
RESIN SYSTEM

CAPITAL COST

ENR 3383
COST MARCH 1981

FIGURE 46

RESIN SYSTEM
ANNUAL COST



AVERAGE COST FOR ELECTRICAL CHARGES ($0.03 to $0.12 kw-hr)

ENR 3383
COST MARCH 1981

FIGURE 47

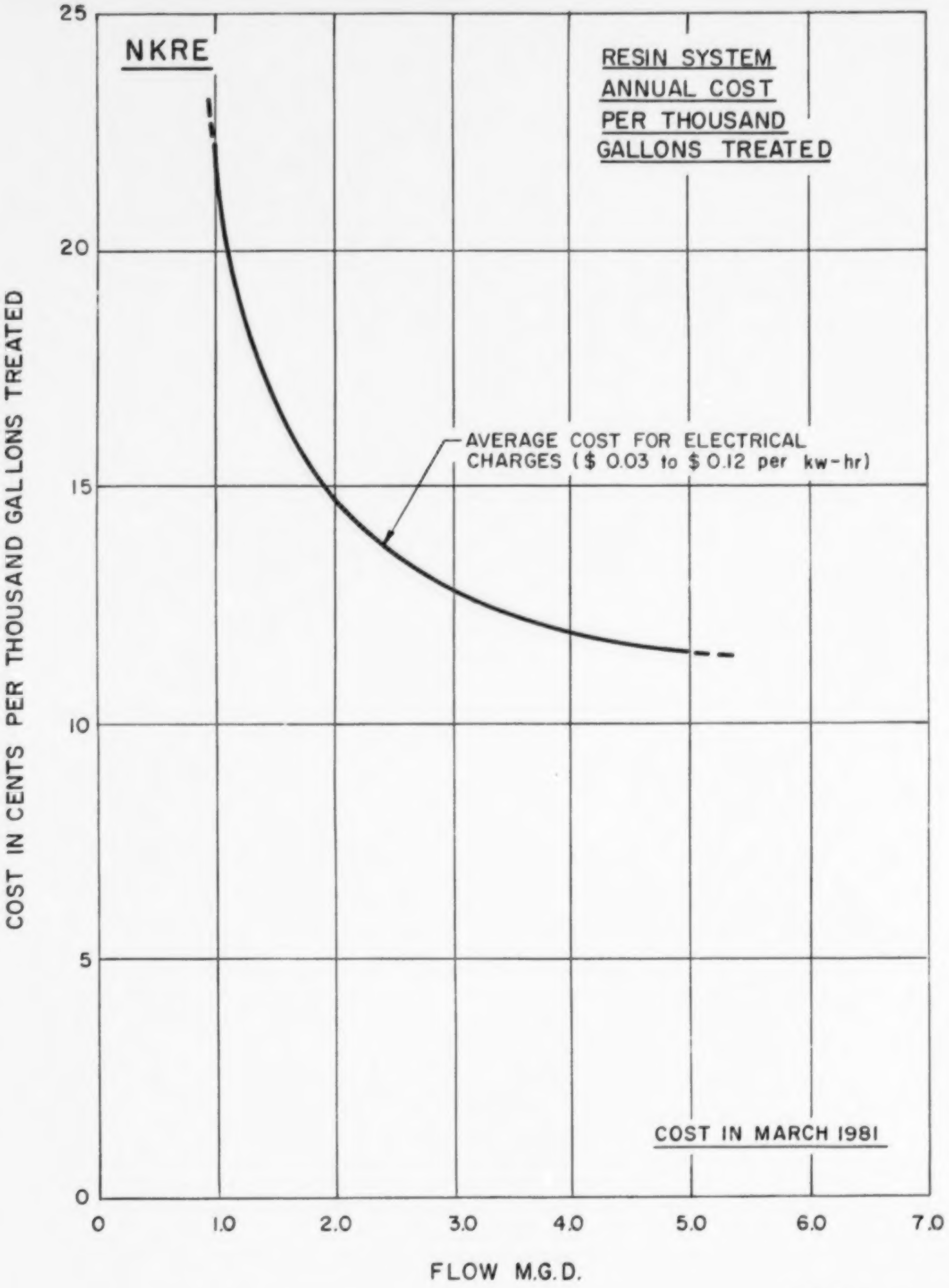

NKRE
RESIN SYSTEM
ANNUAL COST
PER THOUSAND
GALLONS TREATED
AVERAGE COST FOR ELECTRICAL
CHARGES ($ 0.03 to $ 0.12 per kw-hr)
COST IN MARCH 1981
COST IN CENTS PER THOUSAND GALLONS TREATED
25
20
15
10
5
0
0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
FLOW M.G.D.

FIGURE 48

29 Picas 4 11/16" 33%

CAPITAL COST COMPARISON

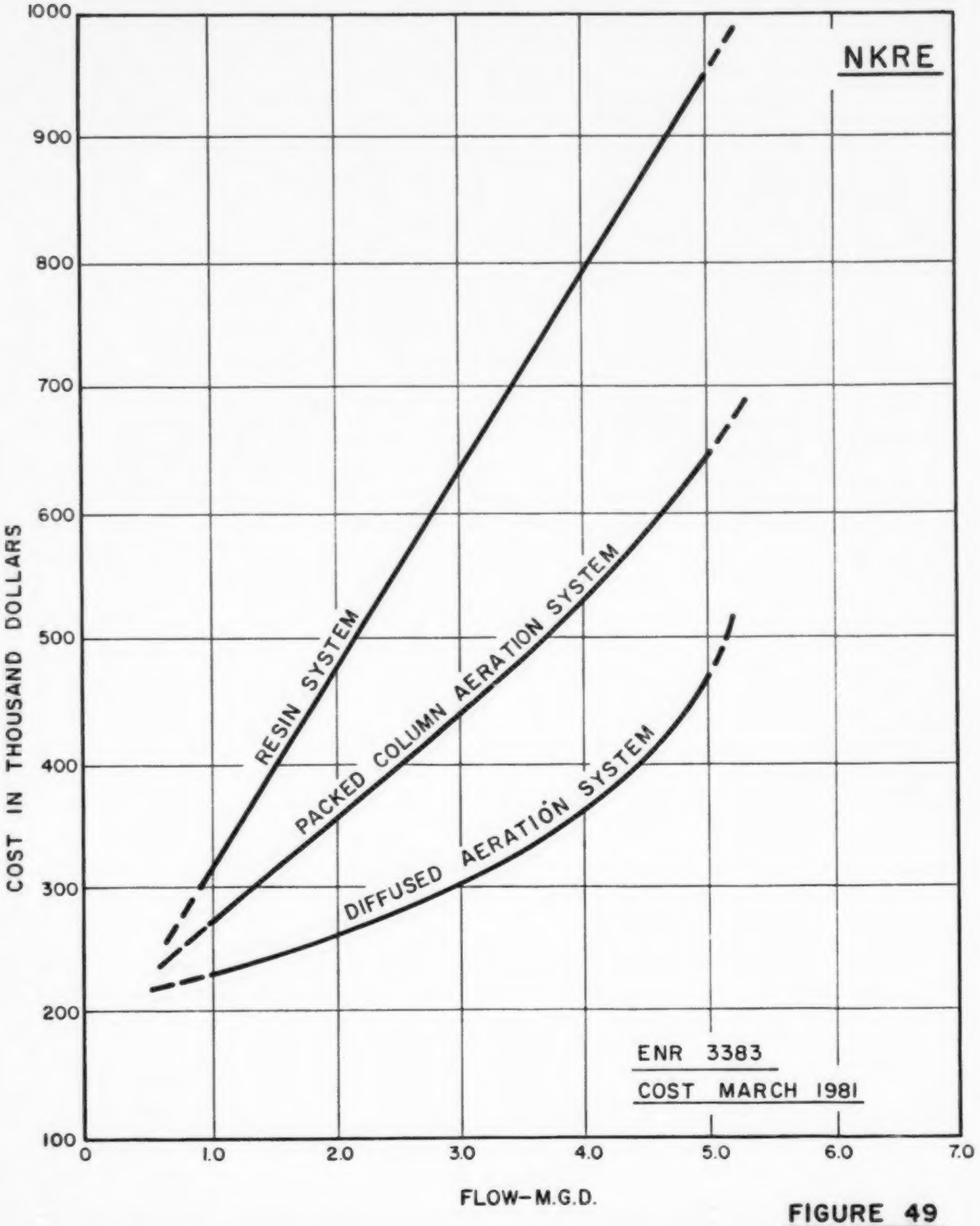


FIGURE 49

COMPARISON OF ANNUAL OPERATING COST
PER THOUSAND GALLONS TREATED
(ENERGY COST at 9¢/kw-hr)

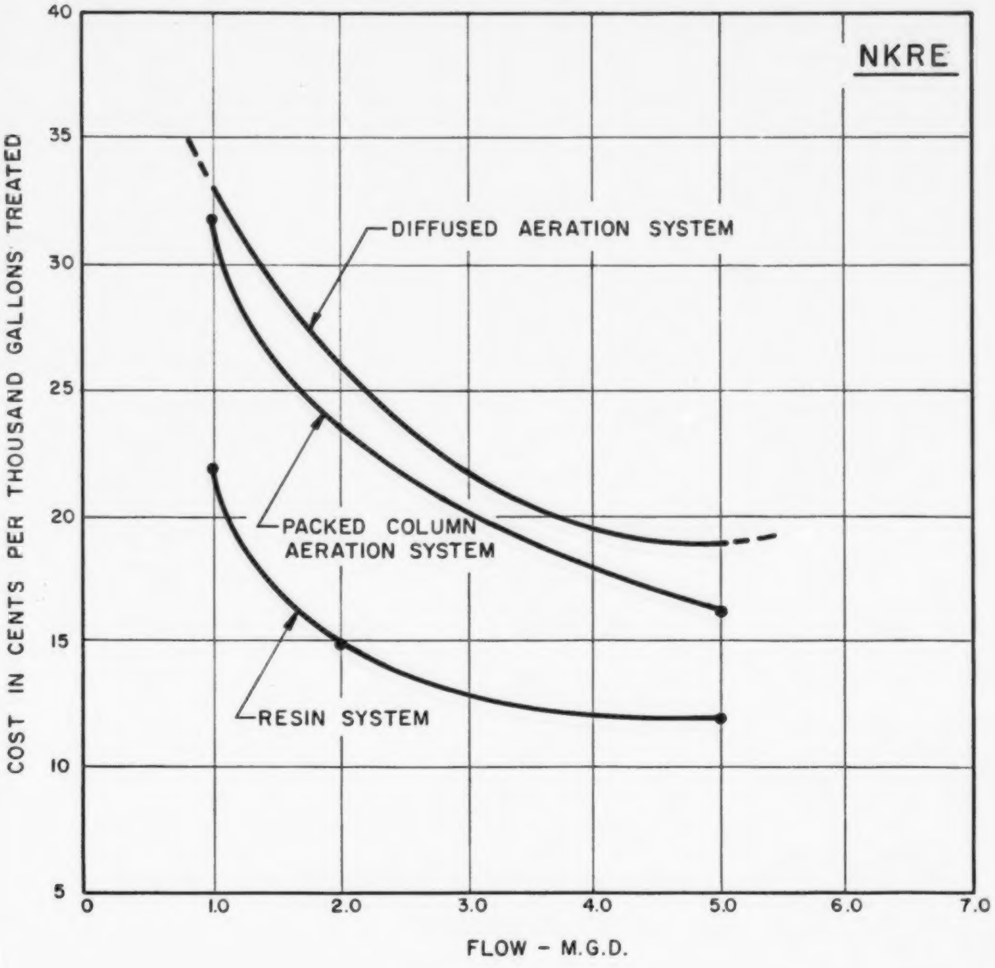


FIGURE 50

APPENDIX A

ANALYTICAL PROCEDURE AND QUALITY CONTROL

The analytical procedure and equipment used were virtually the same as those described in the Phase I report. The only change was the replacement of the recorder by a Varian four speed recorder. This was operated at its lowest chart speed of 2.5 mm/min. This resulted in the appearance of sharper peaks, making it easier to distinguish visually very small peaks from the base line. However, it had no effect on the integrator's perception of peaks.

The performance of the analytical instruments was much better than in the Phase I of the project. In part, this was due to greater experience on the part of the operators. But also, the major problems which caused such lengthy stoppages in the first phase had been solved. Only once was it necessary for a repairman to visit the site for the gas chromatograph. All other repairs were carried out by the analysts.

Stock solutions of each contaminant in methanol were prepared every two months. Every two weeks, standard solutions containing all the pollutants were prepared from these stock solutions by further dilution in methanol. The concentration of contaminants in the samples were determined by comparison to these standards.

To insure reliability of results, a large volume of an aqueous solution of the main contaminants was prepared. Multiple samples of this solution (nearly 100) were set aside for future use which served as an unvarying constant against which laboratory performance was checked. As described in the Phase I report, ten consecutive analyses of these samples were used to determine standard deviations for the three constituents and to establish quality assurance charts. The standard deviations at the 40 to 50 ug/l range were: cis-1,2-dichloroethylene - 1.94 ug/l, trichloroethylene - 3.40 ug/l, tetrachloroethylene - 3.57 ug/l. Quality assurance samples were run every week and had to fall within two standard deviations of the mean for work to proceed. In addition, duplicates of some samples were sent to MERL. Analytical results from the two laboratories were found to be in good agreement.

APPENDIX B

TABLE B-1

PHASE II - PILOT PLANT RESULTS AT GLEN COVE, N.Y.
(All concentrations in ug/l)

Sample Day	Days Operation	Date	Sample	cis	1,1,1	Tri	Tetra	New Ratio Air:Water
0	1	05-22-80	INF-100	47.0	4.7	277	55.7	
1	2	05-23-80	INF-101	43.2	3.6	256	39.3	
			I-CCE-101	0.1	0.1	0.2	0.5	
			II-CCE-101	NM	0.7	0.2	0.2	
			III-RCE-101	NM	0.2	0.3	0.2	
			IV-RCE-101	NM	0.2	0.3	0.9	
			V-RCE-101	NM	0.3	0.5	1.0	
			I-ACE-101	8.9	0.8	30.6	1.9	15:1
			II-PCE-S-101	16.9	1.8	46.8	3.7	15:1
			III-PCE-H-101	11.2	0.9	34.2	3.7	15:1
			IV-CTE-101	15.8	1.9	91.7	11.8	400:1
2	6	05-27-80	INF-102	33.7	3.9	196	38.9	
			I-CCE-102	NM	0.2	0.1	0.6	
			II-CCE-102	NO	NM	0.1	0.1	
			III-RCE-102	NM	0.3	0.2	0.1	
			IV-RCE-102	0.1	0.3	0.2	0.1	
			V-RCE-102	0.4	0.4	0.5	0.5	
			I-ACE-102	8.1	0.6	21.2	1.9	
			II-PCE-S-102	10.5	0.8	30.0	4.1	
			III-PCE-H-102	9.6	0.7	31.6	4.5	
			IV-CTE-102	14.1	1.5	63.6	13.8	300:1
3	9	05-30-80	INF-103	29.1	3.0	170	36.9	
			I-CCE-103	0.1	0.8	0.2	0.2	
			II-CCE-103	NM	0.1	0.2	0.1	
			III-RCE-103	0.1	0.3	0.5	0.1	
			IV-RCE-103	0.2	0.3	0.2	0.1	
			V-RCE-103	0.6	0.5	0.7	0.5	
			I-ACE-103	6.7	0.5	21.5	3.0	
			II-PCC-S-103	10.6	0.8	34.5	5.5	
			III-PCE-H-103	10.6	0.8	30.7	3.4	
			IV-CTE-103	13.7	1.5	70.1	13.0	200:1
4	12	06-02-80	INF-104	28.9	3.1	176	37.3	
			I-CCE-104	NM	0.1	0.2	NM	
			II-CCE-104	NO	0.1	0.2	0.4	
			III-RCE-104	0.3	0.4	0.2	0.1	
			IV-RCE-104	0.4	0.6	0.4	0.2	
			V-RCE-104	1.3	0.6	1.0	0.5	
			I-ACE-104	6.6	0.5	21.2	3.2	
			II-PCE-S-104	8.3	0.8	24.7	3.7	
			III-PCE-H-104	9.9	0.9	29.5	5.3	
			IV-CTE-104	13.2	1.4	68.3	19.4	
5	14	06-04-80	INF-105	29.3	3.3	161	34.8	
			I-CCE-105	NM	NM	0.9	0.1	
			II-CCE-105	NM	0.1	0.1	0.1	
			III-RCE-105	0.6	0.6	0.3	0.2	
			IV-RCE-105	0.7	0.6	0.4	0.2	
			V-RCE-105	1.7	0.7	1.3	1.1	
			I-ACE-104	7.0	0.5	24.5	3.4	
			II-PCE-S-105	9.1	0.7	28.5	4.3	
			III-PCE-H-105	9.8	0.8	26.0	3.6	
			IV-CTE-105	12.9	1.5	64.7	15.5	

(Cont'd)

TYPING GUIDE SHEET

TABLE B-1 (Phase II) - Continued

Sample Day	Days Operation	Date	Sample	cis	1,1,1	Tri	Tetra	New Ratio Air:Water
6	16	06-06-80	INF-106	28.1	3.1	164	33.6	
			I-CCE-106	NM	0.1	0.2	0.1	
			II-CCE-106	NM	0.1	0.1	0.1	
			III-RCE-106	0.8	0.7	0.3	0.2	
			IV-RCE-106	0.9	0.9	0.4	0.2	
			V-RCE-106	2.6	1.1	1.9	1.1	
			I-ACE-106	7.5	0.5	223	3.8	
			II-PCE-S-106	7.4	0.1	27.9	4.7	
			III-PCE-H-106	7.9	0.5	23.5	3.5	
			IV-CTE-106	14.0	1.8	75.5	18.2	
7	19	06-9-80	INF-107	32.9	3.4	174	51.9	
			I-CCE-107	NM	NM	0.1	0.1	
			II-CCE-107	NM	NM	0.2	0.1	
			III-RCE-107	1.0	NM	0.1	0.1	
			IV-RCE-107	1.4	0.9	0.2	0.3	
			V-RCE-107	3.5	0.9	1.5	1.1	
			I-ACE-107	8.5	0.5	20.4	4.0	
			II-PCE-S-106	9.6	0.6	29.1	5.4	
			III-PCE-H-107	9.4	0.7	33.2	6.5	
			IV-CTE-107	14.5	1.3	75.6	21.0	
8	21	06-11-80	INF-108	29.5	3.2	163	45.0	
			I-CCE-108	NM	NM	0.1	0.1	
			II-CCE-108	NM	NM	0.1	0.1	
			III-RCE-108	1.5	1.0	0.1	0.1	
			IV-RCE-108	2.9	1.1	0.6	0.4	
			V-RCE-108	5.5	1.3	3.1	1.7	
			I-ACE-108	9.6	0.6	28.0	5.5	
			II-PCE-S-108	10.4	0.8	33.0	7.4	
			III-PCE-H-108	9.3	0.7	25.3	5.0	
			IV-CTE-108	14.0	1.5	68.3	21.3	550:1
9	23	06-13-80	INF-109	28.3	3.1	154	44.1	
			I-CCE-109	0.1	0.1	0.2	0.1	
			II-CCE-109	NM	0.1	0.1	0.1	
			III-RCE-109	1.8	1.0	0.3	0.1	
			IV-RCE-109	2.4	1.1	0.3	0.1	
			V-RCE-109	4.9	1.0	2.1	1.1	
			I-ACE-109	8.2	0.6	23.6	5.4	
			II-PCE-S-109	10.0	0.7	27.7	5.5	
			III-PCE-H-109	9.3	0.5	25.2	5.0	
			IV-CTE-109	12.6	1.4	63.6	19.6	
10	26	06-16-80	INF-110	34.5	3.5	157	56.6	
			I-CCE-110	0.2	0.1	0.1	0.1	
			II-CCE-110	1.3	0.3	0.7	0.1	
			III-RCE-110	2.4	1.1	0.1	0.1	
			IV-RCE-110	3.8	1.7	0.5	0.1	
			V-RCE-110	7.4	1.2	2.2	1.2	
			I-ACE-110	9.8	0.8	28.0	6.6	
			II-PCE-S-110	10.6	0.9	29.3	6.1	
			III-PCE-H-110	9.3	0.8	24.9	5.4	
			IV-CTE-110	12.5	1.8	57.4	17.9	

(Cont'd)

EPA Form 2350-4 (4-80)

TYPING GUIDE SHEET

TABLE B-1 (Phase II) - Continued

Sample Day	Days Operation	Date	Sample	cis	1,1,1	Tri	Tetra	New Ratio Air:Water
11	28	06-18-80	INF-111	34.8	3.6	169	58.8	
			I-CCE-111	0.2	0.2	0.3	0.1	
			II-CCE-111	1.3	0.4	0.7	0.1	
			III-RCE-111	3.4	1.5	0.3	0.1	
			IV-RCE-111	4.0	1.6	0.5	0.2	
			V-RCE-111	8.1	1.5	3.1	1.7	
			I-ACE-111	8.6	0.7	22.5	5.7	
			II-PCE-S-111	10.1	0.8	25.4	6.4	
			III-PCE-H-111	9.6	0.8	23.7	6.2	
			IV-CTE-111	12.4	1.8	57.0	17.6	
12	30	06-20-80	INF-112	33.8	3.8	161	57.3	
			I-CCE-112	0.3	0.2	0.3	0.1	
			II-CCE-112	1.3	0.4	0.7	0.1	
			III-RCE-112	4.0	1.6	0.3	0.1	
			IV-RCE-112	4.3	1.6	0.5	0.2	
			V-RCE-112	8.4	1.7	3.8	1.9	
			I-ACE-112	10.1	0.9	26.9	5.8	
			II-PCE-112	11.8	1.0	31.1	6.7	
			III-PCE-H-112	10.9	1.0	28.4	6.1	
			IV-CTE-112	13.3	2.0	60.0	22.6	
13	33	06-23-80	INF-113	39.9	4.1	177	58.3	
			I-CCE-113	0.9	0.5	0.3	0.1	
			II-CCE-113	1.7	0.3	0.7	0.1	
			III-RCE-113	5.2	1.9	0.4	0.1	
			IV-RCE-113	6.0	1.7	1.4	0.2	
			V-RCE-113	10.4	2.0	5.0	2.2	
			I-ACE-113	9.5	0.8	24.7	1.1	
			II-PCC-S-113	13.3	1.1	32.0	1.4	
			III-PCE-H-113	14.2	1.7	30.2	1.2	
			IV-CTE-113	12.4	1.4	54.2	17.0	
14	36	06-26-80	INF-114	41.6	3.8	164	48.9	
			I-CCE-114	1.5	0.5	0.4	0.1	
			II-CCE-114	1.9	0.5	0.6	0.1	
			III-RCE-114	6.1	2.1	0.5	0.2	
			IV-RCE-114	7.4	1.9	0.7	0.2	
			V-RCE-114	12.1	2.1	5.3	2.5	
			I-ACE-114	7.1	0.7	19.3	4.9	
			II-PCE-S-114	12.0	1.0	30.2	6.8	
			III-PCE-H-114	12.0	1.0	27.4	5.9	
			IV-CTE-114	13.7	2.0	56.2	18.6	
15	40	06-30-80	INF-115	39.0	3.4	157	44.8	
			I-CCE-115	4.0	1.1	0.3	0.1	
			II-CCE-115	2.7	0.5	0.5	0.1	
			III-RCE-115	7.2	1.9	0.9	0.2	
			IV-RCE-115	8.2	1.9	1.0	0.2	
			V-RCE-115	15.0	2.0	7.6	3.6	
			I-ACE-115	7.7	0.7	19.1	4.3	
			II-PCE-S-115	12.8	1.4	29.3	6.7	
			III-PCE-H-115	12.4	1.6	31.0	7.5	
			IV-CTE-115	13.6	1.8	53.4	19.9	

(Cont'd)

TABLE B-1 (Phase II) - Continued

Sample Day	Days Operation	Date	Sample	cis	1,1,1	Tri	Tetra	New Ratio Air:Water
16	42	07-02-80	INF-116	40.0	3.8	160	50.9	
			I-CCE-116	5.8	1.2	0.5	0.1	
			II-CCE-116	3.2	0.4	0.4	0.1	
			III-RCE-116	8.5	1.7	0.8	0.3	
			IV-RCE-116	12.2	1.8	1.0	0.3	
			V-RCE-116	16.5	2.0	8.2	4.4	
			I-ACE-116	8.8	0.8	22.4	4.9	
			II-PCE-S-116	12.9	1.3	30.2	6.9	
			III-PCE-H-116	13.6	1.2	29.7	7.2	
			IV-CTE-116	15.1	2.2	56.7	20.4	
17	47	07-07-80	INF-117	53.5	4.4	160	69.2	
			I-CCE-117	20.6	3.1	1.5	0.1	
			II-CCE-117	4.3	0.9	0.5	0.1	
			III-RCE-117	10.0	1.8	1.1	0.4	
			IV-RCE-117	19.1	2.7	11.0	3.2	
			V-RCE-117	21.5	2.7	10.7	5.6	
			I-ACE-117	11.2	1.1	24.1	7.0	
			II-PCE-S-117	14.7	1.5	3.5	9.2	
			III-PCE-H-117	12.7	1.4	25.1	6.4	
			IV-CTE-117	16.1	2.1	53.9	20.7	600:1
18	50	07-10-80	INF-118	41.6	4.2	164	53.4	
			I-CCE-118	27.5	4.2	0.9	0.1	
			II-CCE-118	10.6	1.3	0.8	0.1	
			III-RCE-118	10.6	1.9	0.9	0.3	
			IV-RCE-118	9.2	2.0	12.6	3.1	
			V-RCE-118	10.6	2.0	9.9	4.2	
			I-ACE-118	8.7	0.8	20.4	5.4	
			II-PCE-S-118	13.0	1.3	29.5	7.1	
			III-PCE-H-118	13.5	0.9	30.0	7.0	
			IV-CTE-118	17.0	2.2	61.6	22.7	
19	54	07-14-80	INF-119	44.9	4.5	170	61.0	
			I-CCE-119	38.1	3.7	2.5	0.2	
			II-CCE-119	19.7	1.5	1.1	0.1	
			III-RCE-119	12.5	1.5	1.1	0.3	
			IV-RCE-119	19.5	1.9	12.3	3.0	
			V-RCE-119	12.6	1.9	12.1	4.7	
			I-ACE-119	9.2	0.2	21.9	5.5	
			II-PCE-S-119	13.8	1.0	31.3	7.4	
			III-PCE-H-119	13.9	1.2	33.4	8.5	
			IV-CTE-119	16.6	2.2	64.4	22.0	
20	57	07-17-80	INF-120	42.6	4.5	162	58.0	
			I-CCE-120	45.5	5.3	4.2	0.3	
			II-CCE-120	26.4	2.0	1.9	0.1	
			III-RCE-120	12.7	1.4	1.1	0.3	
			IV-RCE-120	18.6	1.7	10.8	2.8	
			V-RCE-120	13.3	1.8	13.0	4.6	
			I-ACE-120	10.4	1.0	23.0	5.8	
			II-PCE-S-120	14.9	1.6	34.6	8.3	
			III-PCE-S-120	14.5	1.5	34.1	8.2	
			IV-CTE-120	16.0	2.6	65.7	24.2	

(Cont'd)

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TABLE B-1 (Phase II) - Continued

Sample Day	Days Operation	Date	Sample	cis	1,1,1	Tri	Tetra	New Ratio Air:Water
21	61	07-21-80	INF-121	38.5	4.5	153	55.1	
			I-CCE-121	48.6	4.0	8.3	0.3	
			II-CCE-121	37.2	3.5	1.9	0.2	
			III-RCE-121	14.7	1.7	1.0	0.5	
			IV-RCE-121	21.0	2.0	11.9	3.0	
			V-RCE-121	15.7	1.9	14.4	5.8	
			I-ACE-121	9.1	0.7	21.5	4.9	10:1
			II-PCE-S-121	16.2	1.2	37.1	8.9	10:1
			III-PCE-H-121	16.9	1.3	40.2	10.3	10:1
			IV-CTE-121	16.4	2.1	62.4	22.0	
22	64	07-24-80	INF-122	30.3	2.7	124	54.5	
			I-CCE-122	52.5	3.9	11.5	0.1	
			II-CCE-122	39.5	2.7	3.8	0.1	
			III-RCE-122	15.2	1.7	1.9	0.4	
			IV-RCE-122	14.5	2.0	8.9	2.3	
			V-RCE-122	20.3	1.9	13.7	4.5	
			I-ACE-122	8.4	0.9	22.6	5.6	
			II-PCE-S-122	15.5	1.1	35.2	9.0	
			III-PCE-H-122	16.3	1.2	38.1	9.4	
			IV-CTE-122	14.6	2.0	53.9	21.0	
23	71	07-31-80	INF-123	29.5	3.0	134	51.8	
			I-CCE-123	36.4	3.5	21.9	0.8	
			II-CCE-123	31.1	2.1	0.3	0.6	
			III-RCE-123	11.9	1.3	0.6	0.4	
			IV-RCE-123	17.4	1.9	12.6	3.2	
			V-RCE-123	22.7	2.0	13.0	4.0	
			I-ACE-123	7.8	0.5	18.2	4.3	
			II-PCE-S-123	16.6	1.3	39.2	10.1	
			III-PCE-H-123	17.9	2.3	47.4	14.7	
			IV-CTE-123	23.0	3.1	87.6	33.6	
24	78	08-07-80	INF-124	29.7	2.9	137	59.0	
			I-CCE-124	38.2	4.0	44.6	2.3	
			II-CCE-124	37.7	3.4	1.6	0.1	
			III-RCE-124	12.1	1.8	0.7	0.5	
			IV-RCE-124	17.3	2.6	12.1	2.8	
			V-RCE-124	22.5	3.0	12.5	3.1	
			I-ACE-124	1.9	0.1	24.2	7.7	
			II-PCE-S-124	10.6	0.9	35.8	10.1	
			III-PCE-H-124	15.0	1.6	47.6	16.3	
			IV-CTE-124	11.8	1.2	56.4	22.5	200:1
25	85	08-14-80	INF-125	32.5	3.3	151	66.6	
			I-CCE-125	38.7	4.0	68.0	3.0	
			II-CCE-125	41.7	3.8	2.2	NM	
			III-RCE-125	15.2	2.1	1.3	0.2	
			IV-RCE-125	20.1	2.0	11.7	2.9	
			V-RCE-125	24.6	1.9	9.4	1.9	
			I-ACE-125	0.8	NM	13.6	3.6	
			II-PCE-S-125	14.3	1.2	40.0	13.8	
			III-PCE-H-125	15.6	2.6	44.1	15.2	
			IV-CTE-125	15.0	1.0	65.7	27.3	400:1

(Cont'd)

TABLE B-1 (Phase II) - Continued

Sample Day	Days Operation	Date	Sample	cis	1,1,1	Tri	Tetra	New Ratio Air:Water
26	92	08-21-80	INF-126	38.0	3.8	148	74.4	
			I-CCE-126	41.4	3.9	85.0	3.8	
			II-CCE-126	44.0	3.9	8.8	0.4	
			III-RCE-126	18.0	2.0	0.9	0.4	
			IV-RCE-126	22.5	2.3	14.3	4.2	
			V-RCE-126	28.0	2.5	19.6	5.7	
			I-ACE-126	1.4	0.9	19.5	5.7	
			II-PCE-S-126	14.8	1.1	40.7	12.6	
			III-PCE-H-126	13.6	1.0	37.8	12.1	
			IV-CTE-126	14.2	1.5	66.0	29.6	300:1
Carbon Column I regenerated 8/25 to 8/27								
27	99	08-28-80	INF-127	37.9	3.9	163	68.3	
			I-CCE-127	NO	NM	0.4	0.1	
			II-CCE-127	48.8	4.5	17.7	0.5	
			III-RCE-127	22.0	1.9	3.1	1.0	
			IV-RCE-127	27.3	2.7	19.0	4.9	
			V-RCE-127	31.9	2.6	25.4	6.4	
			I-ACE-127	10.1	0.6	25.6	6.8	
			II-PCE-S-127	15.9	1.3	44.4	13.7	
			III-PCE-H-127	17.7	2.4	49.7	16.4	
			IV-CTE-127	15.4	2.3	61.6	29.0	
Resin Column V regenerated 9/2 to 9/3								
28	104	09-2-80	I-CCE-128	0.2	NO	0.4	0.1	
29	106	09-4-80	INF-129	52.8	3.7	182	82.1	
			I-CCE-129	1.9	0.3	0.1	0.1	
			II-CCE-129	43.6	4.3	32.5	0.5	
			III-RCE-129	23.3	1.8	4.0	1.0	
			V-RCE-129	0.3	0.1	0.6	0.2	
Resin Column IV superloaded with column V regeneration condensate and regenerated 9/4 to 9/5								
30	107	09-5-80	I-CCE-130	1.8	0.1	0.2	0.1	
			V-RCE-130	0.4	0.2	0.3	0.1	
31	110	09-8-80	I-CCE-131	4.0	0.6	0.4	0.1	
			IV-RCE-131	117.0	4.2	773	184	
			V-RCE-131	0.1	0.3	0.2	0.3	
32	111	09-9-80	I-CCE-132	4.0	0.5	0.2	0.4	
			IV-RCE-132	38.9	2.5	507	153	
			V-RCE-132	0.3	NO	0.3	0.3	
33	113	09-11-80	INF-133	47.7	6.3	177	79.1	
			I-CCE-133	5.8	0.3	0.3	0.5	
			II-CCE-133	48.0	5.5	49.9	2.8	
			III-RCE-133	37.1	3.2	6.1	1.5	
			IV-RCE-133	48.4	NO	508	160	
			V-RCE-133	0.3	NO	0.9	0.3	
			I-ACE-133	12.3	1.8	35.9	10.5	
			II-PCE-S-133	13.5	NO	34.3	8.4	
			III-PCE-H-133	13.8	0.2	35.7	8.5	
			IV-CTE-133	14.8	1.4	65.8	29.7	400:1

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TABLE B-1 (Phase II) - Continued)

Sample Day	Operation	Date	Sample	cis	1,1,1	Tri	Tetra	New Ratio Air:Water
34	120	09-18-80	INF-134	45.4	4.1	164	84.5	
			I-CCE-134	15.6	2.1	0.6	0.4	
			II-CCE-134	42.4	4.3	74.7	0.8	
			III-RCE-134	28.9	2.4	6.4	1.5	
			IV-RCE-134	134.0	NO	836	297	
			V-RCE-134	0.8	NO	0.3	0.4	
			I-ACE-134	14.8	2.0	40.2	12.2	
			II-PCE-S-134	12.5	0.7	30.6	8.6	
			III-PCE-H-134	14.4	0.2	43.0	12.6	
			IV-CTE-134	15.1	1.0	64.7	29.1	500:1
	Spray head for water distribution installed on packed aeration column							
			V-PCE-ST-134	15.4	2.2	43.2	13.6	
35	130	09-23-80	INF-135	43.6	2.8	155	77.2	
			I-CCE-135	26.7	2.6	2.9	0.7	
			II-CCE-135	44.4	4.0	97.6	0.9	
			III-RCE-135	32.3	2.6	10.2	2.6	
			IV-RCE-135	19.6	NM	252	99.0	
			V-RCE-135	2.1	NM	0.5	1.2	
			I-ACE-135	9.5	0.1	24.8	8.0	
			II-PCE-S-135	14.8	0.6	38.4	12.6	
			III-PCE-H-135	15.5	2.2	44.5	16.1	
			IV-CTE-135	13.4	0.6	61.1	28.7	600:1
	Water level in packed aeration column lowered to 1.5 feet above bottom of packing (25% of packing under water)							
			V-PCE-SE-135	10.9	NM	23.0	6.0	
36	132	09-30-80	INF-136	47.9	4.0	153	87.9	
			I-CCE-136	34.2	3.4	12.3	0.6	
			II-CCE-136	44.3	4.4	94.9	0.6	
			III-RCE-136	34.8	2.6	13.0	3.4	
			IV-RCE-136	17.9	NM	188	116	
			V-RCE-136	4.6	1.0	0.8	1.7	
			I-ACE-136	11.8	1.5	29.2	10.0	
			II-PCE-S-136	13.7	NM	24.6	8.9	
			III-PCE-H-136	15.6	0.4	38.5	13.8	
			IV-CTE-136	15.7	0.4	68.0	35.3	
	Carbon column II regenerated 10/1 to 10/3							
37	141	10-09-80	INF-137	47.9	3.9	152	101	
			I-CCE-137	34.6	3.0	23.8	0.7	
			II-CCE-137	2.3	NO	0.1	0.2	
			III-RCE-137	36.6	2.9	17.6	4.7	
			IV-RCE-137	18.0	0.5	162	103	
			V-RCE-137	5.7	NM	2.3	1.6	
			I-ACE-137	13.5	2.0	33.6	13.5	
			II-PCE-S-137	17.0	0.6	38.2	15.0	
			III-PCE-H-137	17.1	NM	41.8	17.2	
			IV-CTE-137	18.6	2.1	71.1	44.2	550:1

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TABLE B-1 (Phase II) - Continued

Sample Day	Operation	Date	Sample	cis	1,1,1	Tri	Tetra	New Ratio Air:Water
38	148	10-16-80	INF-138	47.4	3.4	146	96.8	
			I-CCE-138	47.8	4.5	43.4	0.9	
			II-CCE-138	10.5	0.7	0.1	0.2	
			III-RCE-138	33.4	2.4	14.5	4.0	
			IV-RCE-138	33.9	1.9	300	211	
			V-RCE-138	9.4	0.8	3.3	3.7	
			I-ACE-138	21.8	1.9	51.9	24.7	
			II-PCE-S-138	17.7	1.0	29.3	11.6	
			III-PCE-H-138	18.4	1.1	32.9	14.0	
			IV-CTE-138	17.9	1.8	54.6	40.5	500:1
	Water level in packed aeration column lowered to bottom of packing (no packing under water)							
39	156	10-24-80	INF-139	54.0	4.1	152	114	
			I-CCE-139	53.4	4.3	57.7	2.4	
			II-CCE-139	30.1	2.5	1.5	0.4	
			III-RCE-139	36.1	2.8	19.1	5.8	
			IV-RCE-139	9.0	0.5	15.2	18.3	
			V-RCE-139	17.4	1.3	5.3	5.2	
			I-ACE-139	23.2	1.7	63.7	36.3	
			II-PCE-S-139	13.0	0.7	21.9	10.5	
			III-PCE-H-139	16.7	1.0	29.9	15.5	
			IV-CTE-139	20.3	2.1	66.7	51.8	
40	163	10-31-80	INF-140	59.2	4.7	165	127	
			I-CCE-140	46.9	3.6	70.1	1.8	
			II-CCE-140	40.0	3.1	5.2	0.3	
			III-RCE-140	45.7	3.5	27.7	8.4	
			IV-RCE-140	15.6	1.1	8.4	16.1	
			V-RCE-140	21.5	1.5	7.7	6.1	
			I-ACE-140	25.0	2.1	74.2	44.8	
			II-PCE-S-140	14.4	0.9	24.7	13.1	
			III-PCE-H-140	17.2	1.2	34.7	20.1	
			IV-CTE-140	22.7	2.1	76.7	56.6	400:1
41	169	11-06-80	INF-141	55.4	4.2	149	126	
			I-CCE-141	50.9	3.9	81.8	2.8	
			II-CCE-141	50.4	3.8	11.1	0.6	
			III-RCE-141	43.6	3.4	27.6	10.1	
			IV-RCE-141	22.8	1.4	60.0	45.8	
			V-RCE-141	25.6	2.1	8.9	6.4	
			I-ACE-141	40.2	2.8	107	67.6	
			II-PCE-S-141	16.9	0.8	34.7	20.1	
			III-PCE-H-141	16.8	0.9	30.8	18.6	
			IV-CTE-141	25.2	2.3	83.6	62.8	300:1
42	175	11-12-80	INF-142	50.3	3.0	130	122	
			I-CCE-142	50.5	3.6	83.9	4.2	
			II-CCE-142	48.9	3.2	13.5	0.3	
			III-RCE-142	46.9	2.9	32.1	12.5	
			IV-RCE-142	17.5	0.8	31.3	29.3	
			V-RCE-142	30.5	1.7	8.8	7.2	
			I-ACE-142	22.4	0.9	53.5	36.8	
			II-PCE-H-142	7.6	0.3	12.3	7.7	
			III-PCE-S-142	9.5	0.4	18.8	12.4	
			IV-CTE-142	20.9	1.3	63.2	60.0	

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TABLE B-1 (Phase II) - Continued

Sample Day	Operation	Date	Sample	cis	1,1,1	Tri	Tetra	New Ratio Air:Water
	Resin column III regenerated 11/12 to 11/14							
43	181	11-18-80	INF-143	52.2	2.9	138	123	
			I-CCE-143	54.5	3.6	93.1	3.2	
			III-RCE-143	0.2	NO	0.4	0.2	
			IV-RCE-143	22.1	1.2	22.0	26.8	
			I-ACE-143	22.6	1.0	47.8	32.9	5:1
			II-PCE-S-143	11.7	0.3	17.7	10.4	5:1
			III-PCE-H-143	16.4	0.5	28.7	19.1	5:1
	Carbon column I regenerated again 11/18 to 11/19							
44	187	11-24-80	INF-144	53.4	3.5	142	141	
			I-CCE-144	3.5	0.2	0.1	0.1	
			II-CCE-144	56.9	3.3	35.0	0.4	
			III-RCE-144	0.2	NO	0.1	0.1	
			IV-RCE-144	29.1	1.4	24.6	25.1	
			V-RCE-144	37.8	1.7	14.5	9.5	
			I-ACE-144	22.0	1.0	41.4	30.5	
			II-PCE-S-144	14.1	0.5	19.0	12.3	
			III-PCE-H-144	15.7	0.5	23.5	15.5	
45	201	12-8-80	INF-145	57.7	3.8	127	156	
			I-CCE-145	27.7	2.2	1.7	0.4	
			II-CCE-145	64.0	4.3	65.3	2.0	
			III-RCE-145	0.7	0.1	0.1	0.3	
			IV-RCE-145	43.4	2.5	28.3	25.7	
			V-RCE-145	49.8	2.9	23.4	14.4	
			I-ACE-145	29.2	1.7	57.3	46.4	
			II-PCE-S-145	19.6	1.3	29.9	24.4	
			III-PCE-H-145	24.0	1.8	43.3	31.9	
46	215	12-22-80	INF-146	58.5	3.8	130	142	
			I-CCE-146	46.9	3.1	20.0	1.0	
			II-CCE-146	64.3	3.8	85.7	3.7	
			III-RCE-146	2.4	0.5	0.2	0.4	
			IV-RCE-146	51.7	3.0	20.6	16.5	
			V-RCE-146	58.7	3.1	31.5	17.8	
			I-ACE-146	23.1	1.4	37.5	31.4	
			II-PCE-S-146	18.4	1.2	23.4	17.9	
			III-PCE-H-146	21.4	1.5	56.8	57.1	
47	229	1-5-81	INF-147	77.7	4.4	126	166	
			I-CCE-147	67.2	4.1	41.8	3.7	
			II-CCE-147	78.1	4.6	97.7	9.8	
			III-RCE-147	4.1	0.3	0.3	0.5	
			IV-RCE-147	68.9	3.5	29.1	18.8	
			V-RCE-147	70.9	3.6	32.6	17.0	
			I-ACE-147	32.5	1.6	51.0	49.0	
			II-PCE-S-147	16.1	0.3	25.5	23.9	
			III-PCE-H-147	23.1	1.2	31.3	28.4	

TABLE B-1 (Phase II) - Continued

Sample Day	Days Operation	Date	Sample	Cis	1,1,1	Tri	Tetra	New Ratio Air:Water
48	236	1-12-81	INF-148	63.5	4.4	123	154	
			II-CCE-148	65.0	5.4	53.2	4.8	
			II-CCE-148	67.3	5.2	123	11.1	
			III-RCE-148	9.2	0.9	0.5	0.4	
			IV-RCE-148	68.1	6.0	42.4	21.5	
			V-RCE-148	63.9	3.5	29.9	9.3	
			I-ACE-148	26.0	2.0	47.2	46.8	
Resin Column IV Regenerated 1/13 - 1/14								
49	238	1-14-81	INF-149	64.2	4.0	117	159	
			V-RCE-149	69.4	4.0	41.9	20.8	
Resin Column V superloaded with Column IV regeneration condensate and regenerated 1/14 - 1/15								
50	243	1-19-81	INF-150	63.2	4.4	121	162	
			I-CCE-150	72.8	4.6	68.4	10.1	
			II-CCE-150	72.9	4.6	119	7.9	
			III-RCE-150	13.4	1.2	0.6	2.3	
			IV-RCE-150	2.5	n.o.	8.0	8.1	
			V-RCE-150	n.o.	n.o.	2.6	5.2	
			I-ACE-150	35.5	1.4	51.8	52.4	
			II-PCE-S-150	19.2	1.0	23.1	21.1	
			III-PCE-H-150	18.5	1.2	29.4	27.0	
51	250	1-26-81	INF-151	73.3	5.2	134	200	
			I-CCE-151	77.8	5.2	73.5	11.7	
			II-CCE-151	78.0	5.4	130	10.9	
			III-RCE-151	20.6	3.0	1.2	1.7	
			IV-RCE-151	1.1	n.o.	3.7	3.1	
			V-RCE-151	0.1	n.o.	2.2	2.5	
			I-ACE-151	31.3	3.7	45.1	44.1	
			II-PCE-S-151	25.8	2.7	23.0	21.4	
			III-PCE-H-151	26.3	3.4	34.0	31.7	
52	254	1-30-81	INF-152	78.7	4.9	150	207	
			III-RCE-152	19.9	0.6	1.0	2.9	
			IV-RCE-152	n.o.	n.o.	1.8	2.8	
			V-RCE-152	n.o.	n.o.	3.5	11.4	

APPENDIX C

Serial No. 6005
TN-8068
33-81-55

CL Report No. 81-24
CL Logbook 186012

CORROSION REPORT

Group 33, Monomer Process Research

DATE: February 20, 1981

TO: Eric G. Isacoff

cc: G. H. Beasley
G. W. Harmon
C. A. Panza

FROM: Bart S. Frechem

PROCESS/PRODUCT: AMBERSORB XE-340: PILOT PLANT TESTS

FINDINGS:

Mild steel coupons were installed in plastic flow tanks at the XE-340 pilot plant in Glen Cove, NY. Three sets of coupons were exposed; for each set one coupon was placed in the resin layer and the other coupon was suspended in the water above the resin.

Exposure - Set		Exposure Time (days)	Corrosion Rate MPY	Comments
Water	-1	106	11.0	Uniform corrosion and slight conc. cell attack.
Water	-2	106	10.0	Uniform corrosion and slight conc. cell attack.
Water	-3	177	8.5	Uniform corrosion and conc. cell "craters".
Resin	-1	106	7.4	Uniform corrosion with slight irregular surface.
Resin	-2	106	7.7	Uniform corrosion with slight irregular surface.
Resin	-3	177	5.5	Slightly irregular surface.

REMARKS:

Photographs of the coupons, before and after cleaning, are included in copies of the report sent to Mr. Isacoff and the writer. The tests were originally designed to compare the corrosion of mild steel in carbon to its corrosion in XE-340. One set of coupons was to be exposed in the carbon system, one in the XE-340 system, and the third in water only, as a control. In actuality, all three sets of coupons were exposed in the XE-340. Consequently, the tests results are valid only as an absolute measure of the corrosion in the XE-340 system. Nothing can be said, from this data, about the relative corrosivity of XE-340 and carbon. The question was never one of whether or not the steel will corrode; steel exposed to water (containing oxygen) will corrode. The question was, how does XE-340 affect the corrosion

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of steel compared to granulated carbon. It is not even valid to compare the corrosion rate of a coupon above the resin to one imbedded in the layer of resin, and say that the difference is purely a measure of the effect of XE-340. One would expect the corrosion of a coupon embedded in a granular solid to differ from one exposed in open water, for theoretical reasons that have little to do with the chemical nature of the solid. These factors would include the concentration of oxygen in the water and its diffusion through the granular bed, and the effect of the solid on the growth and nature of the rust scale.

Bart S. Frechem

Bart S. Frechem

dbw
Attachment

WATER
RESIN
WATER
RESIN

Photo A

Mild steel coupons exposed to water/XE-340 system.

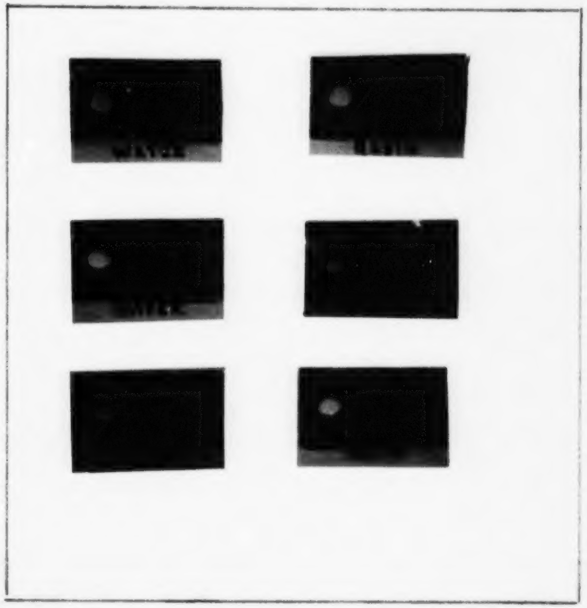
WATER
RESIN
WATER

Photo B

Same as Photo A after cleaning. Note concentration cell corrosion on coupons exposed to water only.

APPENDIX D

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
CINCINNATI, OHIO 45268

DATE: January 29, 1981

SUBJECT: Organic Contaminants in the Well Water at Glen Cove, New York

FROM: Walter A. Feige, Project Officer Walter A. Feige

TO: Harvey Lunenfeld, EPA Region II, Water Supply Representative

The purpose of this memorandum is to inform you that recent sampling of Carney Street Well No. 22 (the source used in our research cooperative agreement CR 806355) has resulted in the identification of 3 additional organic compounds not previously observed. They are:

1,1-dichloroethylene*	0.3 ug/L
1,1-dichloroethane*	4.6 ug/L
1,2-dichloroethane*	10.8 ug/L

*identified by GC retention times only

Also, in recent months the average concentrations of trichloroethylene (TCE) and tetrachloroethylene (PCE) in the well have changed. Presently, TCE averages about 130 ug/L (vs. 205 ug/L previously) and PCE averages about 160 ug/L (vs. 75 ug/L previously).

We cannot attribute a reason for the water quality changes, but surmise that the wave front has shifted after several years or that a recent dumping occurred.

cc: D. Ruggiero